Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

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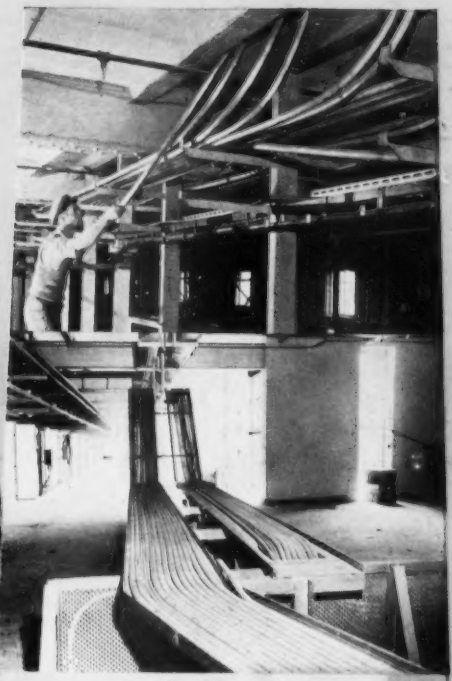
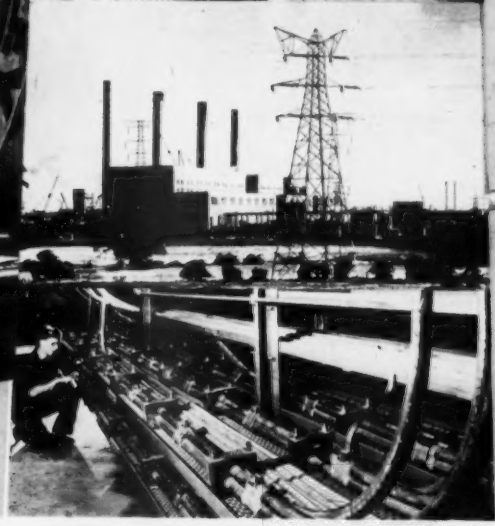


Keadby
Power Station
Lincolnshire



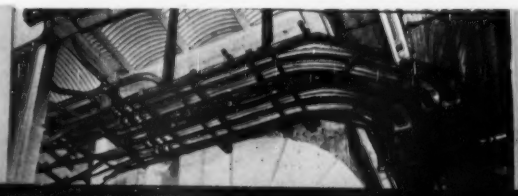
Pasir Panjang
Power Station
Singapore

Littlebrook 'C
Power Statior
Kent

Littlebrook
Power Stat
Kent

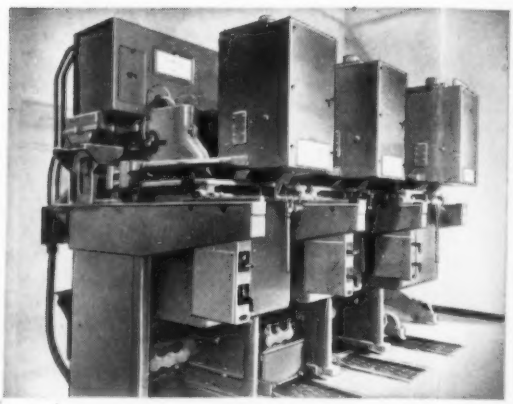
POWER CABLES BY HENLEY

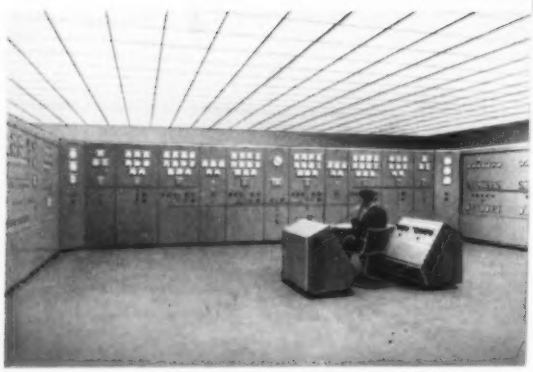
W. T. HENLEY'S TELEGRAPH WORKS CO LTD., 51-53 HATTON GARDEN, LONDON, E.C.1 Tel: CHAncery 6822



Pretoria 'B
Power Stat
South Afri

GENERATOR SWITCHGEAR AT CALDER HALL





The generators at the Calder Hall Power-station of the Atomic Energy Authority are controlled by Reyrolle 11-kV 500-MVA and 750-MVA switchboards and their associated control-boards

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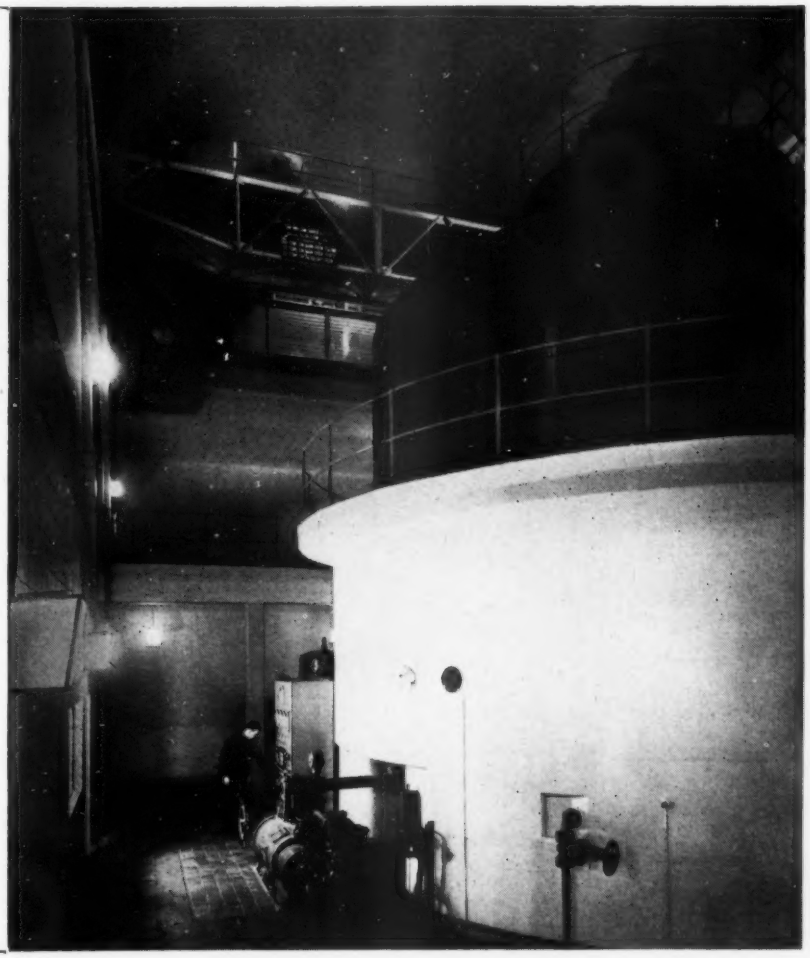
A. REYROLLE & COMPANY LIMITED, HEBBURN, COUNTY DURHAM, ENGLAND

Largest hydro-electric set in Scotland

The underground power station at Clachan contains the largest hydro-electric generating set in Scotland. This unit, supplied by The ENGLISH ELECTRIC Company, comprises a 40,000 kW alternator driven by a 56,000 h.p. reaction turbine operating under a head of 897 feet—the highest head of any reaction turbine in the North of Scotland Hydro-Electric Board's system.



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hydro-electric equipment

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Hydro-electric Department, Stafford.

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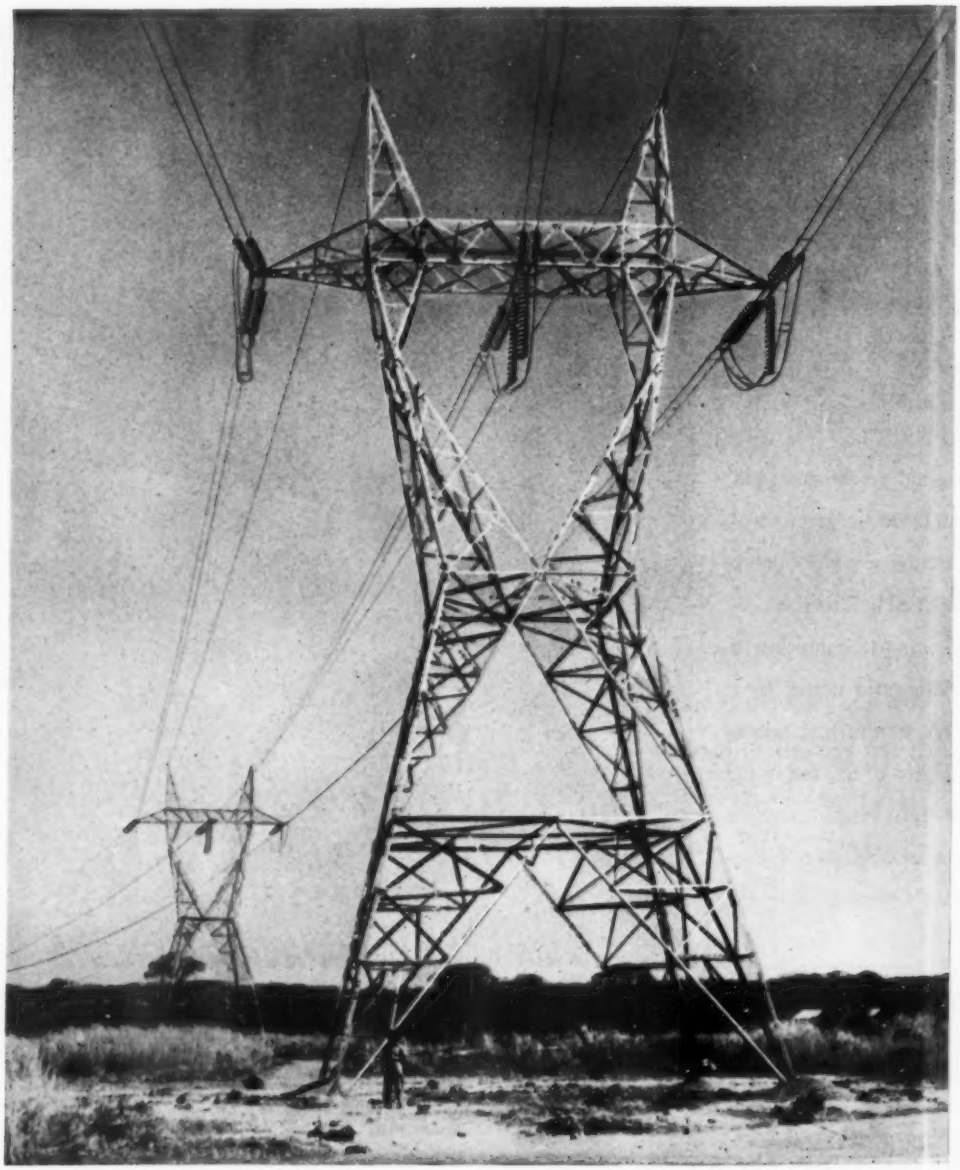
HIGH-GRADE SPECIALIZED MANUFACTURERS — 35 YEARS OF EXPERIENCE



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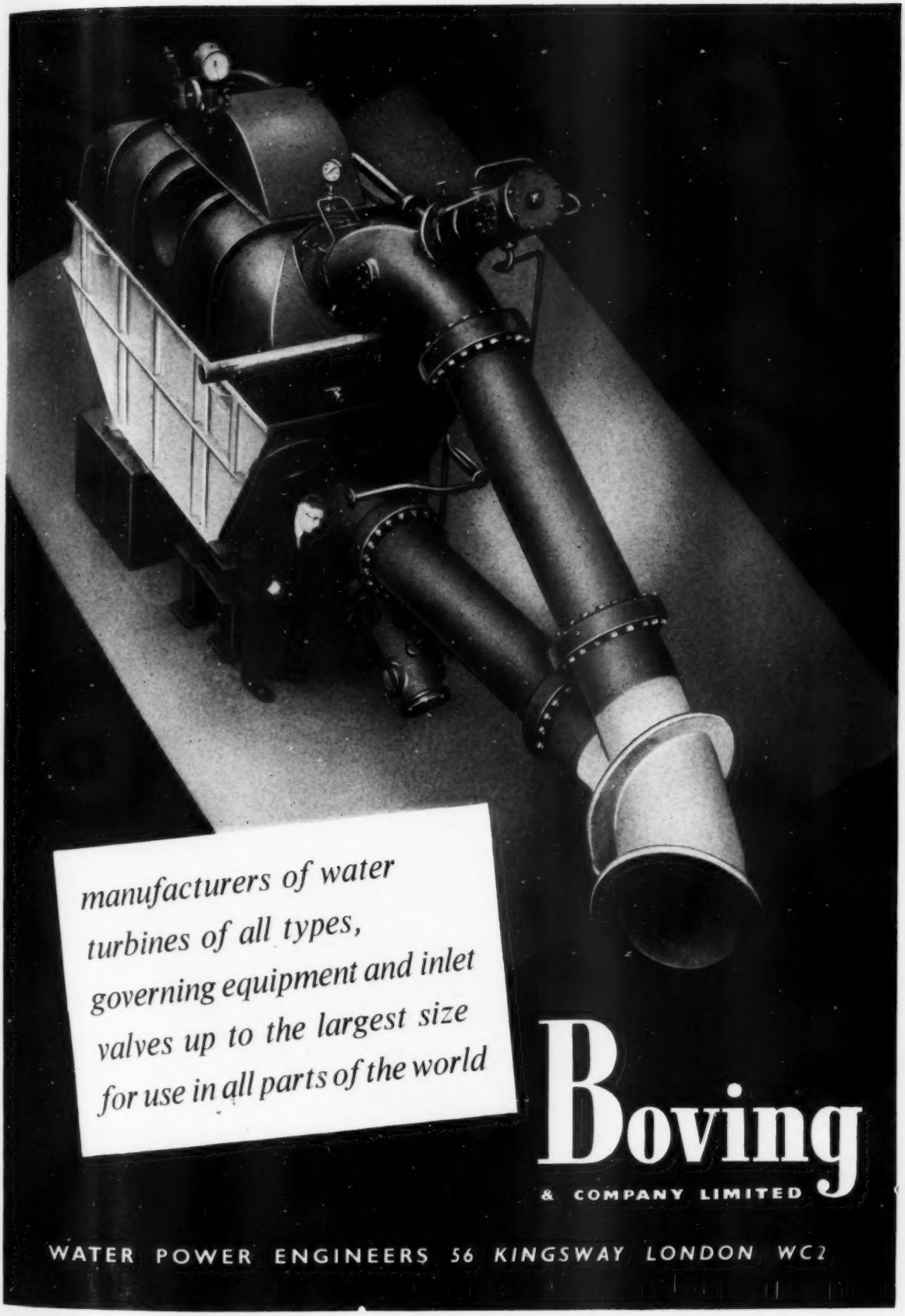
CATALOGUES AND PRICES ON REQUEST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Output **63,000 H.P.,** speed 750 r.p.m., max. head **455 m.**

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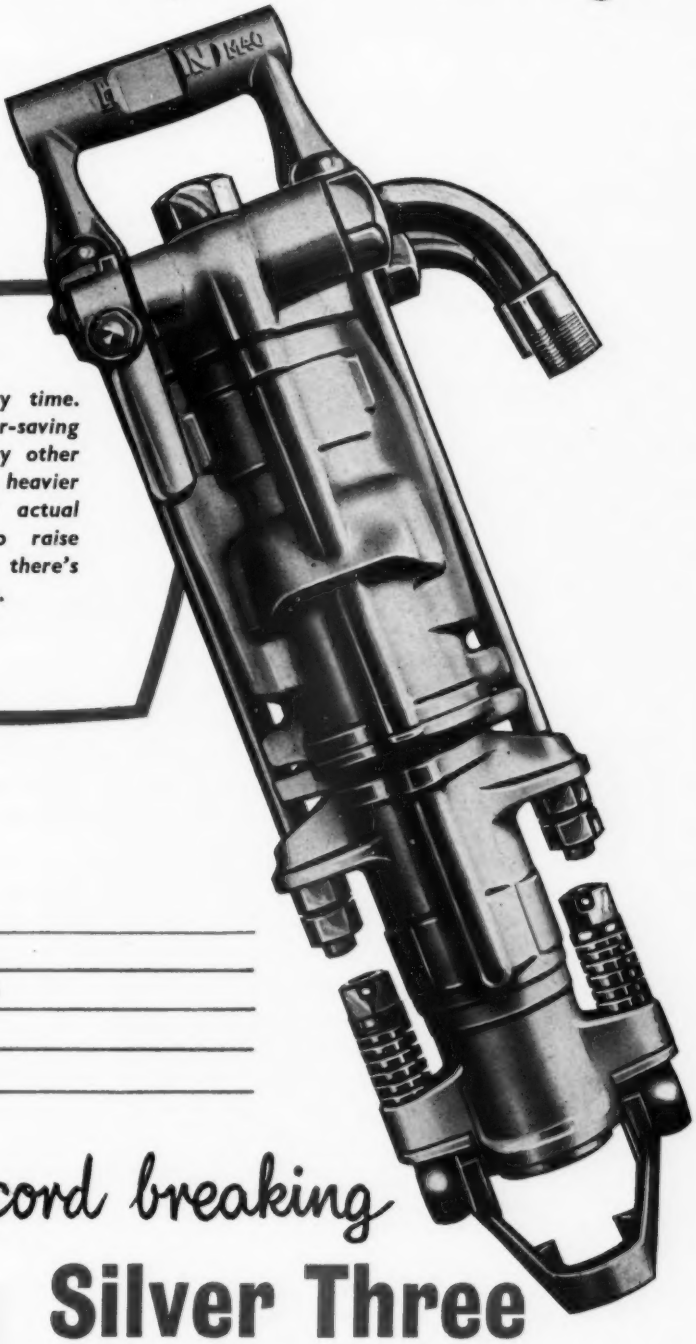

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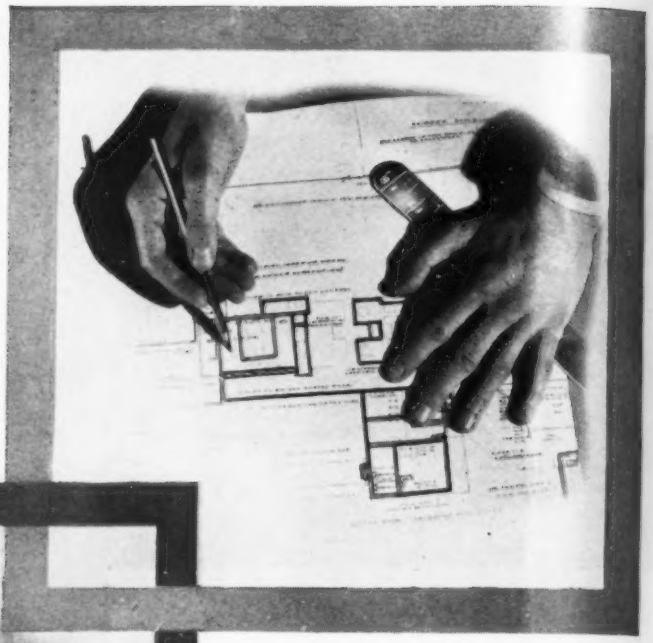
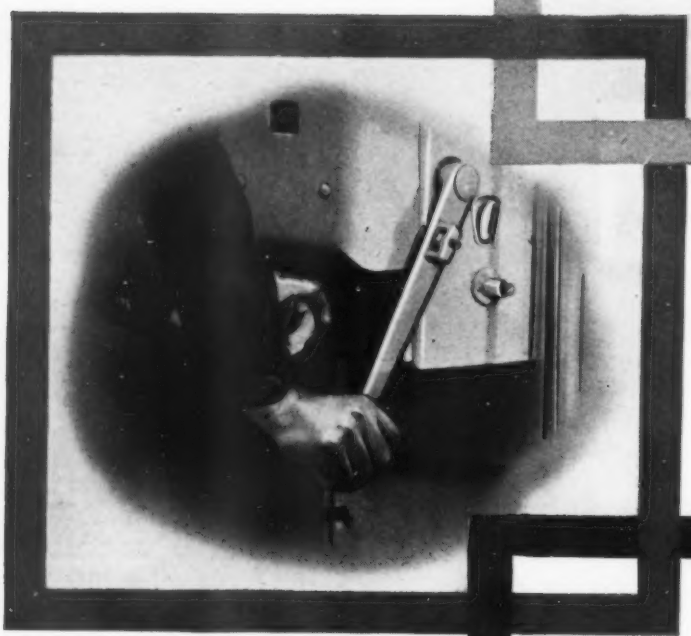
From drawing board





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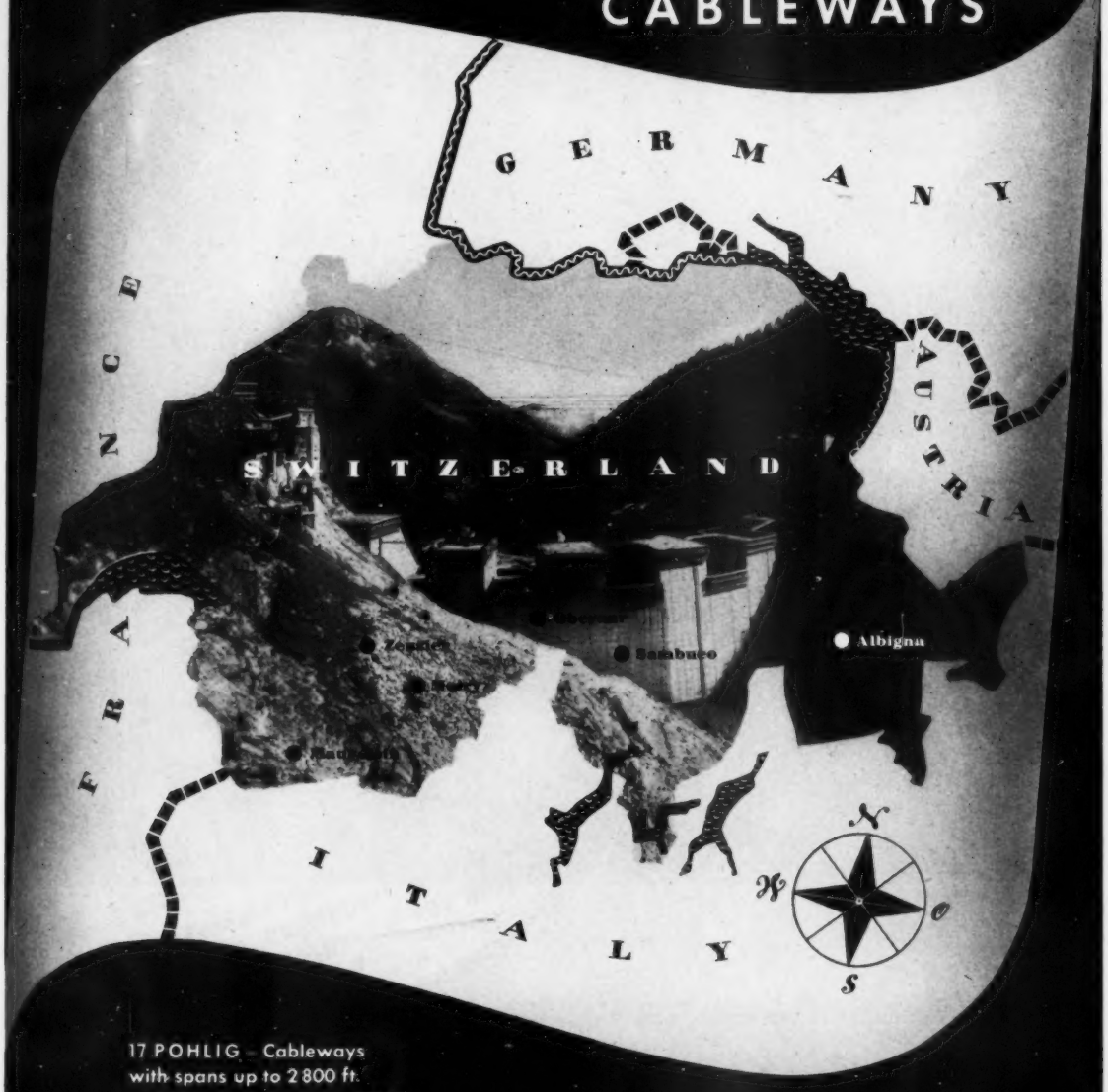
POHLIG
CABLEWAYS



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with spans up to 2 800 ft.
and lifting heights up to 900 ft.,
travelling speeds up to 1 200 ft. per minute
and a carrying capacity
of up to 20 tons per each cableway
have been erected and commissioned
during the last 6 years
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Trasformatori trifasi da 60/60/60/60 MVA
225/125 ± 2 × 5%/6,3/12 kV - 50 Hz
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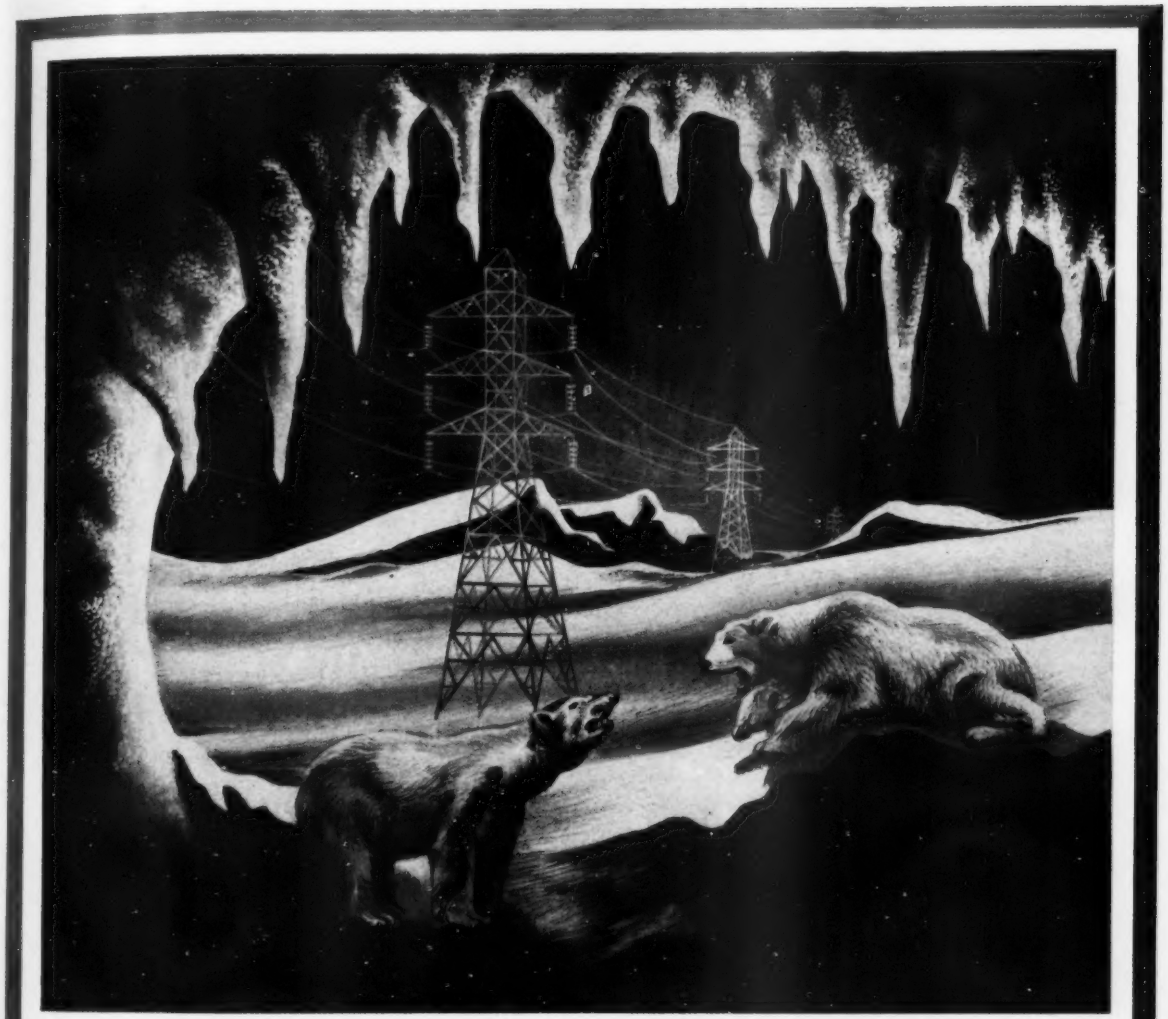
MACHINES ET APPAREILLAGES POUR ENGENDRER, TRANSFORMER ET UTILISER L'ÉNERGIE ÉLECTRIQUE
MACHINES AND EQUIPMENT FOR GENERATING, TRANSFORMING AND UTILISING ELECTRIC POWER
MASCHINEN UND AUSRÜSTUNGEN ZUR ERZEUGUNG, UNFORMUNG UND AUSNÜTZUNG VON ELEKTRISCHER ENERGIE
ASG
ANSALDO-SAN GIORGIO
GENOVA
GENOVA (ITALIA) - MURA DI SANTA CHIARA, 1 - TELEFONO: 586.741 TELEGRAMMI: SERAS-GENOVA

The Painter's View



Freeze, freeze, thou bitter sky

NOT yet are there any power lines in the icy regions of the poles, but, if the demand came, the severe climatic conditions would be just another natural hazard to be overcome by Painter Brothers' engineers because they are specialists.

Because we have always been Tower Specialists and have developed our own fabrication methods which ensure accuracy and interchangeability; because we have had nearly thirty years' experience of hot dip galvanising, and because we have our own Tower Testing Station to prove the behaviour of structures under every sort of loading condition, Painter Brothers' towers are Towers of Strength.

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Overhead Electrical Transmission Towers and Poles; Radio Masts; Callender-Hamilton Bridges.

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WATER GATES
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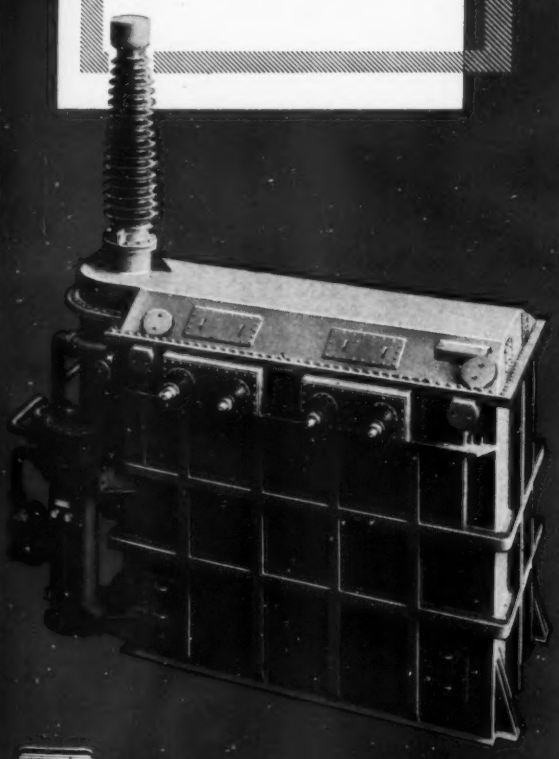
EQUIPMENT

CAP DE LONG: Self-hooped penstock for the Pragnères Power Station, in the Pyrénées.
Head 1,252 metres, Flow 14,6 cu.m./sec.
Diameter 2.25 to 1.60 metres, Power 200,000 H.P.

PASSY: Penstock bridge over the River Arve, in the French Alps.
Span 72 metres, Diameter 3 metres.

ETABTS. BOUCHAYER & VIALLET
SOCIETE DAUPHINOISE d'ÉTUDES & de MONTAGES
GRENOBLE - FRANCE

719,000 kVA of FERRANTI Transformers for the Alcan Project



NEW CONTRACT

Ferranti Ltd. have been awarded a further order by the Aluminum Company of Canada Ltd., for 3-71,000 kVA, single phase Generator Transformers stepping up to 301,400 volts

These units will form the second 213,000 kVA bank of generator transformers to be supplied by Ferranti Ltd., for installation in the now famous "Power Station inside a mountain" of the Alcan Project at Kemano, British Columbia. The transformers will have aluminium windings, and it is believed that they will form the largest bank of transformers with aluminium windings in the world. This order brings the total number of transformers supplied or under construction by Ferranti Ltd. for the Alcan Project to 13 units of a total capacity of 719,000 kVA, to the value of 1,210,000 dollars.

FERRANTI

FERRANTI LTD · HOLLINWOOD · LANCS

London Office: KERN HOUSE, 36 KINGSWAY, W.C.2

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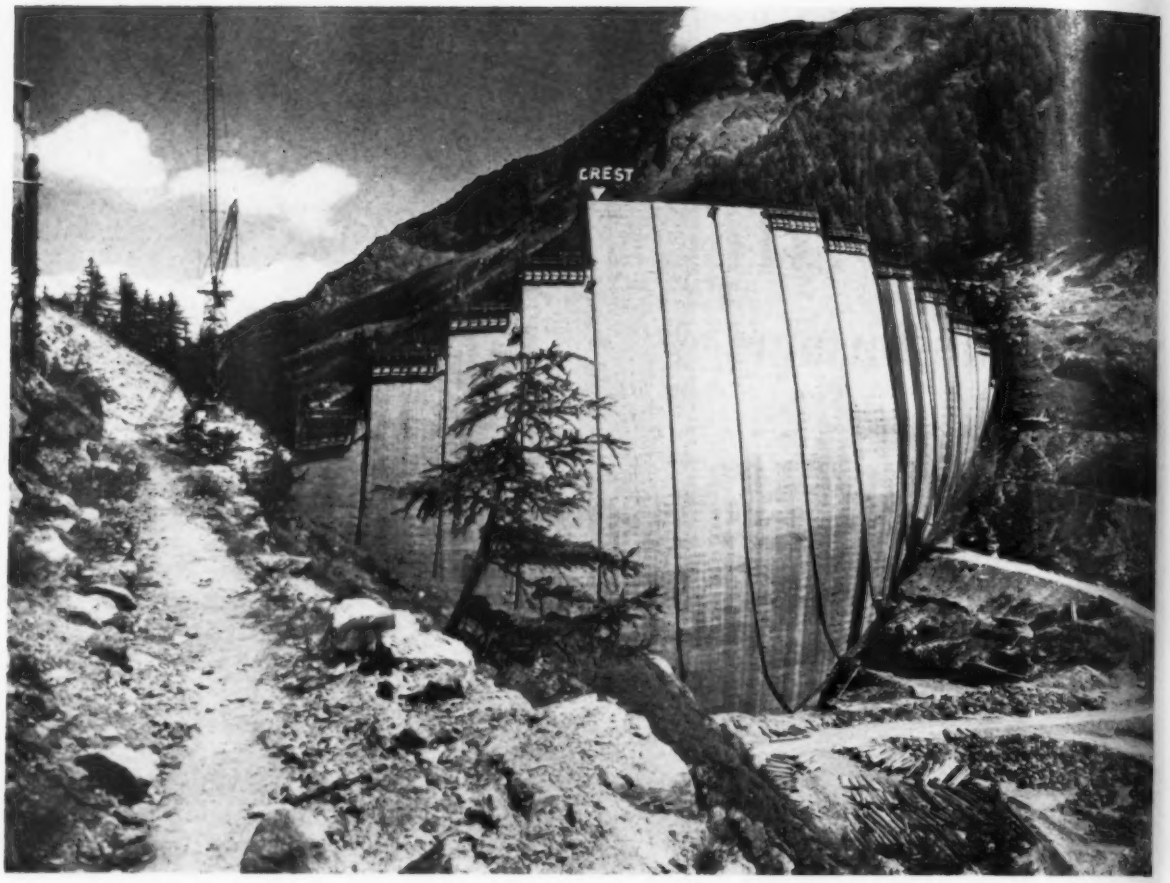

BEAUREGARD DAM ON THE DORA DI VALGRISANCHE RIVER · ITALIAN ALPS
AT EL. 5,810 ft. a.s.l. - UNDER CONSTRUCTION

PRINCIPAL: **S.I.P.** SOCIETÀ IDROELETTRICA PIEMONTE - TURIN

TYPE: ARCH GRAVITY - MAX. HEIGHT: 434 ft. - CREST LENGTH: 1,280 ft. - VOLUME: 550,000 cu. yds.

DOTT. ING. G. TORNO & C.

BUILDING & CIVIL ENGINEERING CONTRACTORS & CONSULTANTS

7, VIA ALBRICCI, **MILAN, ITALY** - CABLE ADDRESS: **IDROTORNO**

For reconstruction work on the L.C.C. Northern Outfall, Beckton, Richard Costain Limited use the most modern type of oil-flooded rotary compressor.

These oil-flooded Rotary Compressors cost far less in upkeep

Plant engineers now specify this new revolutionary design—the CP "Power Vane" Rotary Compressor. By dispensing with clutch, crankshaft, valves and pistons, the cost and time loss on maintenance is virtually eliminated. This simple, two-stage vane type rotary compressor gives greater power for its size and weight, and smoother operation. "Power Vane" Rotary Compressors run entirely in oil and are oil-cooled. Other design features include centralised instrument panel, fully-automatic safety controls and non-detachable radiator doors. There is a "Power Vane" Rotary Compressor for every type and size of job. Ask for Catalogue 58-C for a full description of models from 120 to 600 cu. ft. capacity.

POWER VANE **ROTARY COMPRESSORS**

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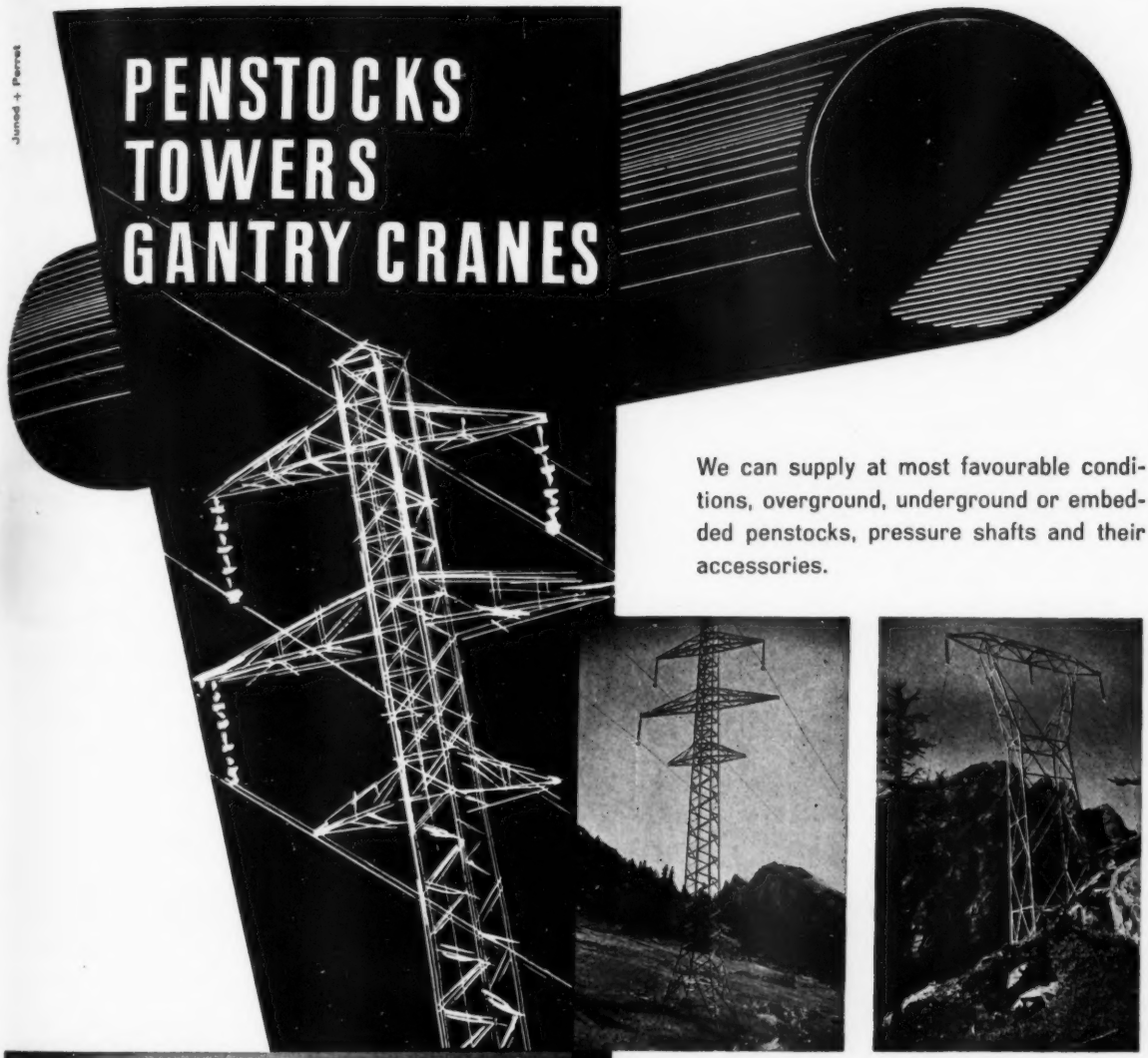

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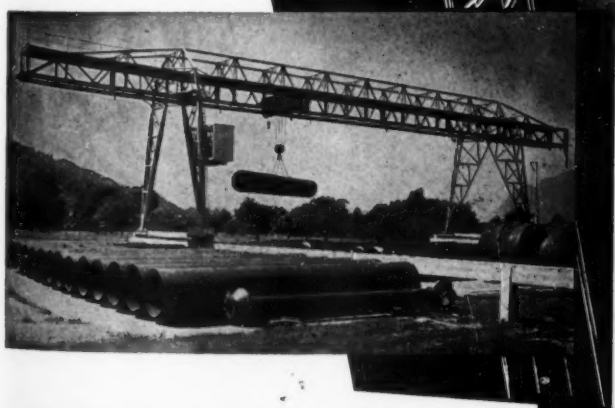

Gantry crane, lifting capacity 3 to 25 tons, distance between rails 36 m., 2 overhangs of 12 m., total length 60 m.

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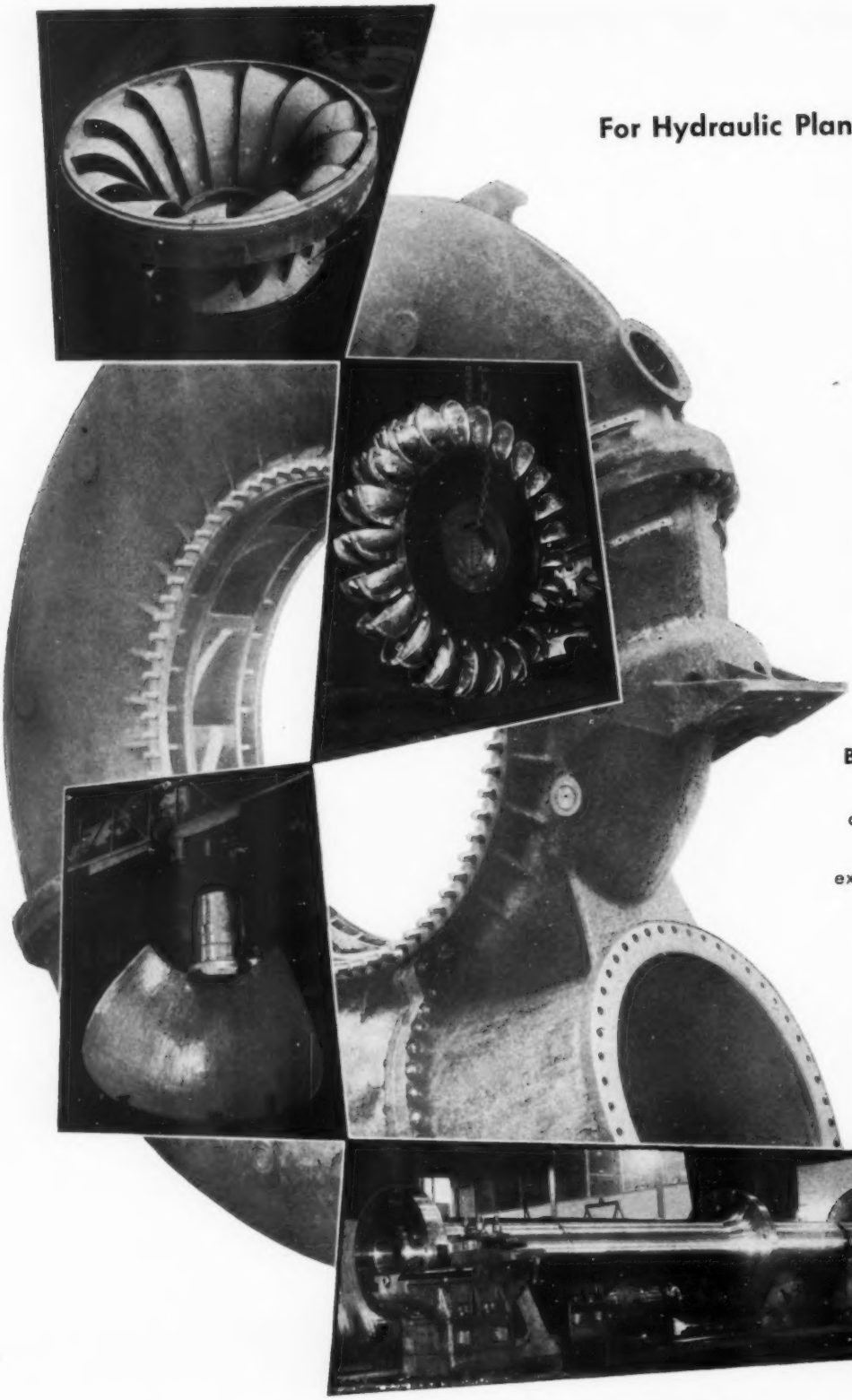

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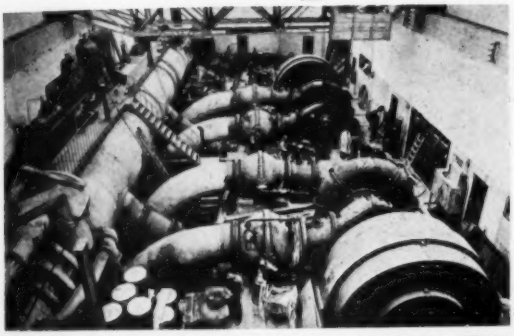
GLOCKNER-KAPRUN HYDRO-ELECTRIC SYSTEM

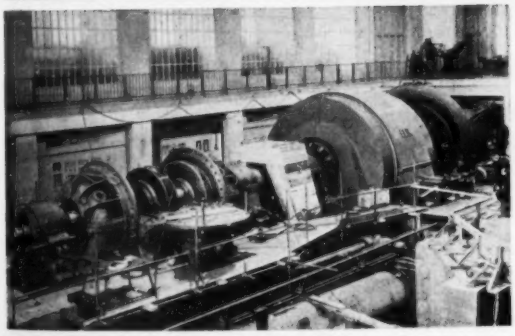
ATELIER PEBAL

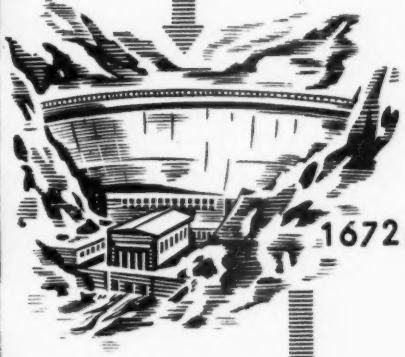


Moell Pumping Station at Mooserboden Reservoir: Two three-phase, squirrel-cage motors, direct-on-the-line start, each 9,100 h.p at 494 r.p.m.

2036 m

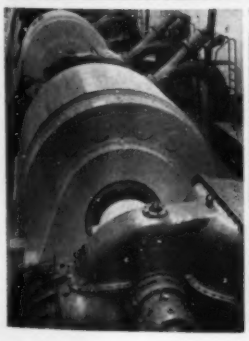
Kaprun Upper Stage: Two combined motor/alternators, each 62,000 kVA at 500 r.p.m. driving Europe's most powerful pumps for lifting storage water from Wasserfallboden to Mooserboden; also the related unit transformers, and automatic control of the synchronous machines.

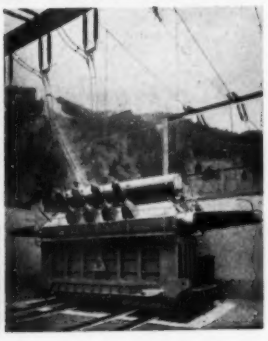


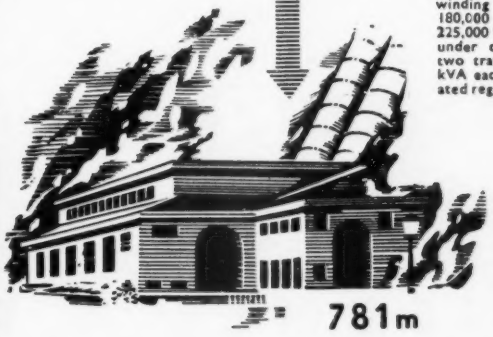


1672 m

Kaprun Main Stage: Two alternators, each 70,000 kVA, 500 r.p.m., with unit transformers; one three-winding transformer 180,000 kVA, rated at 225,000 kVA (a second one under construction), and two transformers 100,000 kVA each, all with associated regulating equipment.





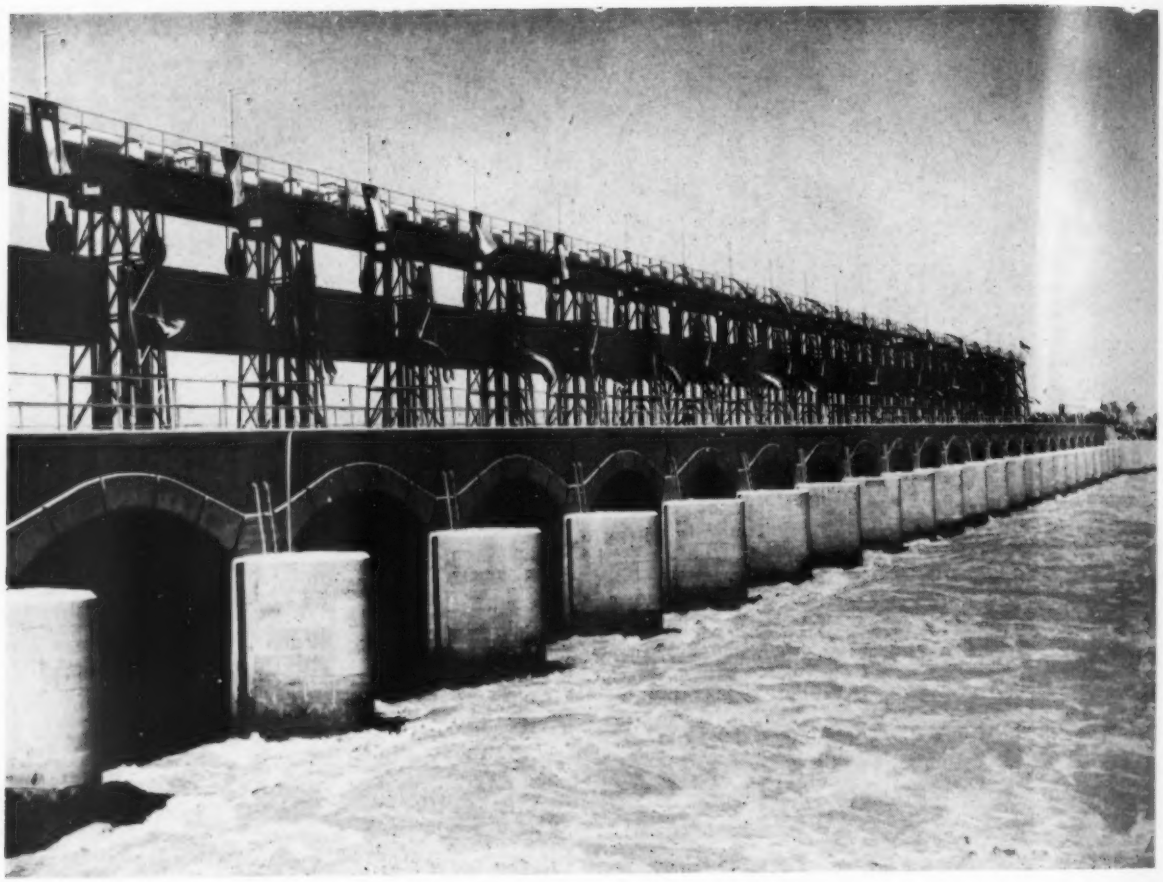


781 m

Generators, Motors and Transformers well in excess of one million kVA installed by

"ELIN"
VIENNA AUSTRIA

RAPIER WATER CONTROL GATES



Sluice and Lock Gates and Operating Gear designed, manufactured and erected for the following important installations in Iraq :

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SAMARRA	WARRAR
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for

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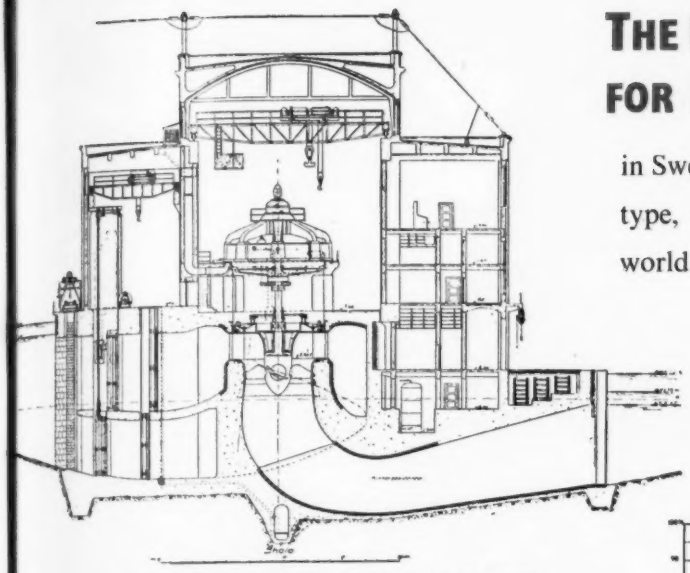
RANSOMES & RAPIER LTD.

IPSWICH — ENGLAND

THE KMW KAPLAN TURBINE FOR LILLA EDET POWER STATION

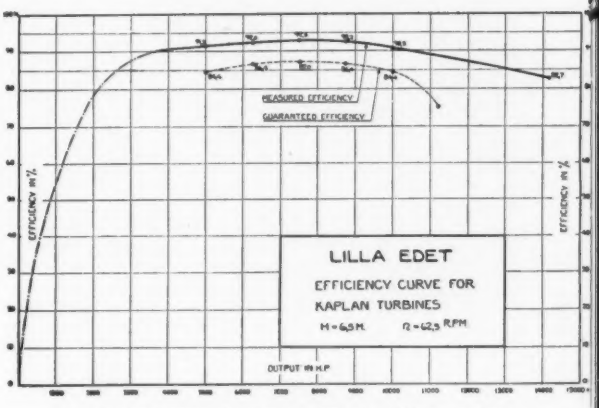
in Sweden opened up the market for this turbine type, not only in Sweden but throughout the world.

KMW



THE SWEDISH STATE POWER STATION AT LILLA EDET

KMW undertook the building of Kaplan turbines 35 years ago, and in 1921 we proposed a turbine of this type with a runner dia. of 5.8 m. for the Lilla Edet Power Station, belonging to the Swedish State. The Swedish Royal Board of Waterfalls were farsighted enough to order this turbine the following year. It was started up and became a complete success. Efficiencies above 90% were obtained from 3,500 HP to 10,200 HP with fully automatic regulation of both runner blades and guide vanes and no oil leakage and no difficulties in regulation and operation were experienced.



LILLA EDET. EFFICIENCY CURVE FOR KAPLAN TURBINES.

Since that time KMW have delivered about 280 units with a total output of 4.2 Million HP, this output being greater than that obtained by any other turbine manufacturer.

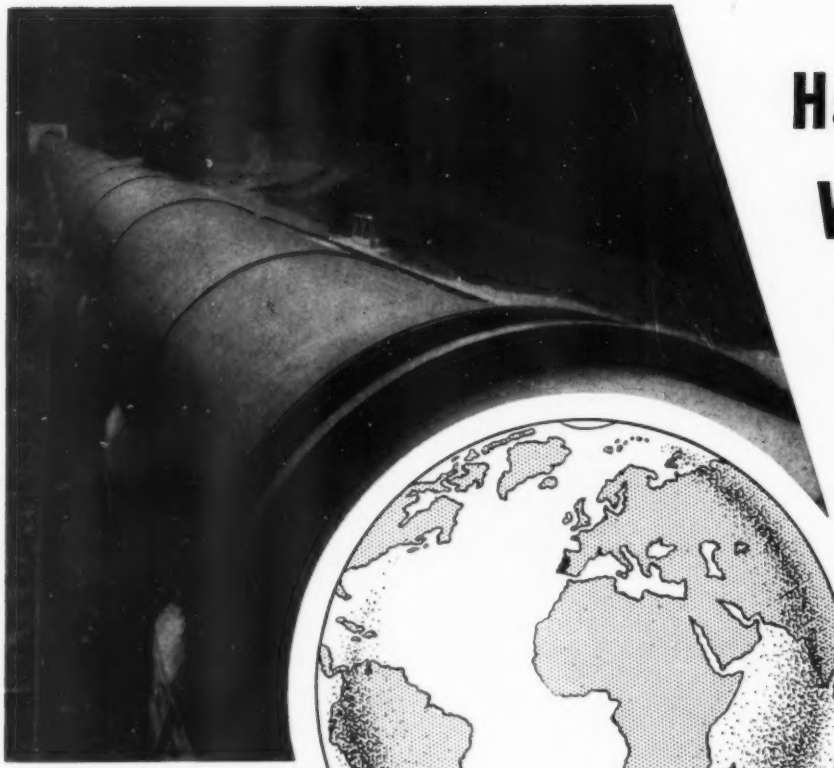
Among the largest KMW turbines of Kaplan type can be mentioned:

Year	Customer	Plant	Country	Head		Output	Speed
				Met.	Feet	B.H.P.	r.p.m
1929	Ryska Handelsdelegationen, Stockholm	Swir	USSR	11.0	36.1	37500	75
1931	Kungl. Vattenfallsstyrelsen, Stockholm	Vargön	Sweden	4.3	14.1	15200	46.9
1935	OY Rouhiala AB, Jääski	Rouhiala	Finland	17.6	57.8	33000	100
1937	Kungl. Vattenfallsstyrelsen, Stockholm	Stadsforsen	Sweden	27.0	88.5	47700	125
1939	Kungl. Vattenfallsstyrelsen, Stockholm	Hojum	Sweden	31.0	101.6	63900	136.3
1946	Kungl. Vattenfallsstyrelsen, Stockholm	Hölleforsen	Sweden	27.0	88.7	57500	125
1947	Egyptian Government, Cairo	Aswan Dam	Egypt	27.0	88.7	65000	100
1949	Bergeforsens Kraft AB, Sundsvall	Bergeforsen	Sweden	22.75	74.6	48300	115
1950	Kungl. Vattenfallsstyrelsen, Stockholm	Ligga	Sweden	40.5	132.8	105650	125
1953	Kungl. Vattenfallsstyrelsen, Stockholm	Umluspen	Sweden	30.0	98.4	54900	150
1954	Balforsens Kraft AB, Kramfors	Balforsen	Sweden	31.0	101.7	51110	150
1956	Kungl. Vattenfallsstyrelsen, Stockholm	Järkvissle	Sweden	13.6	44.6	59450	75

Among these turbines the Vargön unit is one of the biggest in the world with regard to the dimensions, having a runner diameter of 8 m. (26.2 feet), and the Ligga unit with regard to the output, this being 105,650 HP.

AB KARLSTADS MEKANISKA WERKSTAD KARLSTAD SWEDEN

Representatives in Canada: A. Johnson & Co. (Canada) Ltd., 1428 Shell Tower Building, Montreal 2



Harnessing Water Power *all over the Globe*

For Hydro-Electric installations
South Durham Service is complete.
It embraces the design, manufacture, installation and final test of all Piping supplied. The advice and experience of our technical staff and drawing office are readily available for the assistance of engineers engaged in the planning of Hydro-Electric projects.

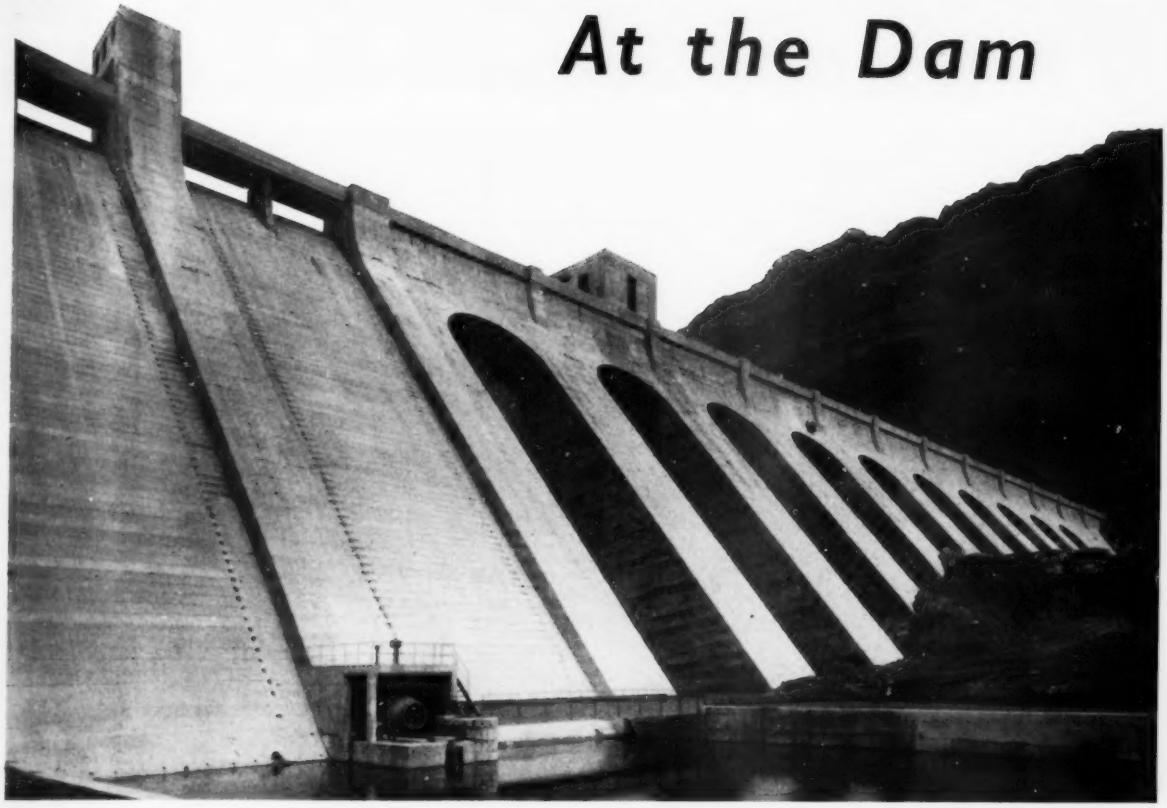
Illustration shows Hydro-Electric pipeline—erected, welded and tested by South Durham for the Hydro-Electric Project at Vila Nova, Portugal.

SOUTH DURHAM

STEEL PIPES

SOUTH DURHAM STEEL & IRON CO. LTD., (incorporating Cargo Fleet Iron Co. Ltd.)
Malleable Works, Stockton-on-Tees, Co. Durham. Telephone: Stockton 66117.

At the Dam



NEEDLE VALVES

Glenfield Needle Valves, hand and electrically operated, are installed on many hydro-electric works throughout the world, in all sizes up to 9 ft. dia. and for a wide range of working pressures up to 1,200 ft. head, for efficient regulation of freely discharging scour or compensation water.

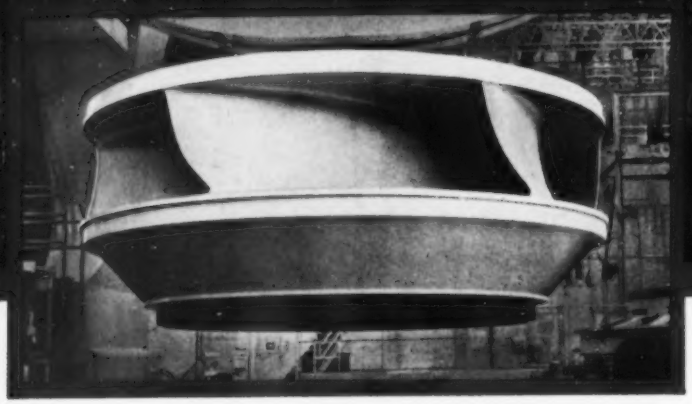
To safeguard against destructive erosion in reception areas, it is usual practice to incorporate in the valve structure a Glenfield Jet Disperser which eliminates any possibility of damage downstream.

Glenfield

GLENFIELD & KENNEDY, LIMITED, KILMARNOCK

Head Office and Works: KILMARNOCK, SCOTLAND.

World's Largest Reversible P

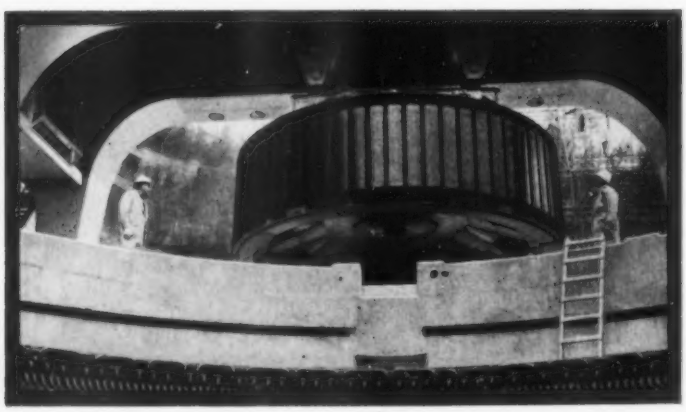


Shipped in three sections, this world's-largest Francis runner was assembled at the dam site.

At Hiwassee Dam, adding a pump-turbine, rather than a conventional turbine-generator unit, is expected to increase peaking capacity as much as 44,000 kw during extended periods of low water.

NOW Installed and Operating at TVA's Hiwassee Dam

— storing off-peak power as re-usable water



Here, the 310-ton, 329-inch diameter generator-motor rotor is ready to be lowered into stator.

ALLIS-

Pump-Turbine Combination

● In a single unit, this pioneering hydroelectric installation operates as a 70,000-kva turbine-driven generator when rotating in one direction, and as a 102,000-hp motor-driven pump when it rotates in the reverse direction.

As a turbine it has a maximum capacity of 112,000 hp to generate valuable peaking power during demand periods.

As a pump it has a rated capacity of 3900 cubic feet per second against 205-ft head — nearly three times the water requirements of New York City. When off-peak power is available from other plants on the TVA system, this unit — with its 102,000-hp motor, the world's largest — pumps water into storage for re-use during peaking periods.

This reversible pump-turbine is further proof that you get *MORE* design advances *first* from Allis-Chalmers — builder of over 15 million installed hydraulic turbine horsepower.

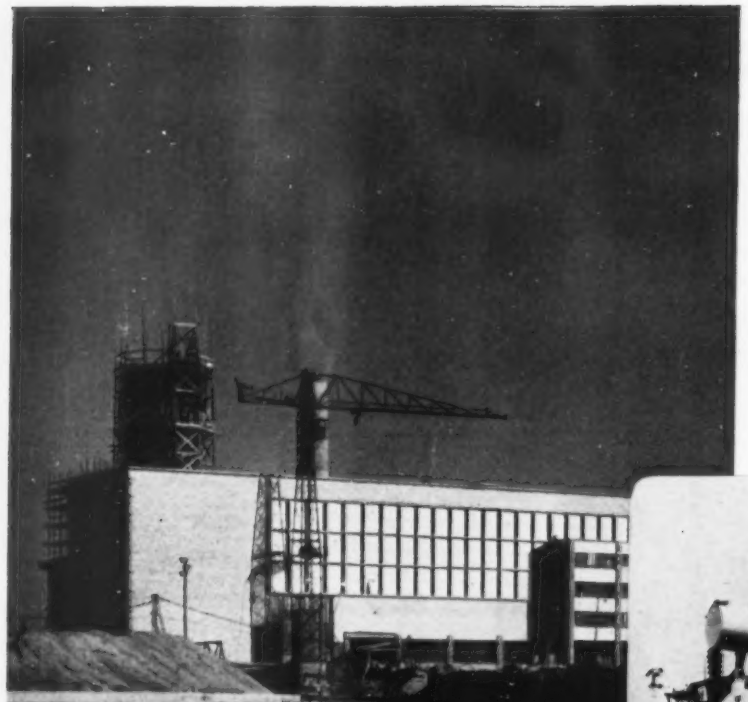
For all or any part of *your* needs, call the Allis-Chalmers representative near you, or write Allis-Chalmers, Power Equipment Division, Milwaukee 1, Wisconsin, U.S.A. Manufacturing plants in the United States and Canada.

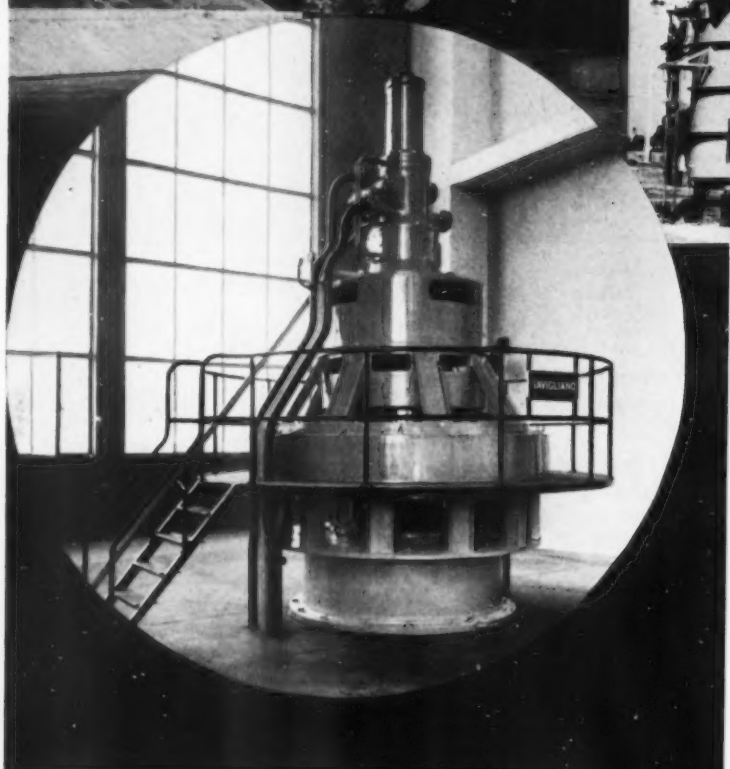
In this cutaway view, size of pump-turbine unit is indicated by man standing on upper level.

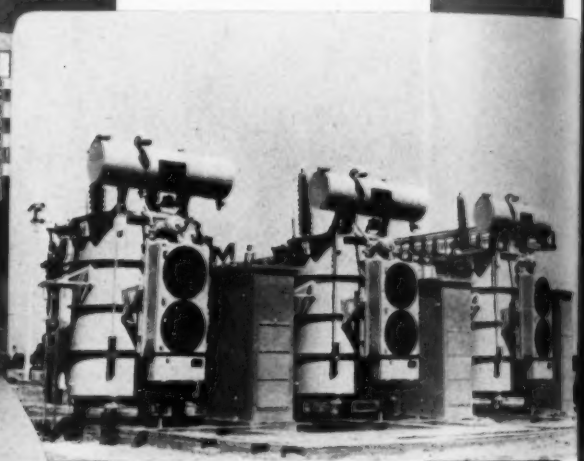
ALLIS-CHALMERS

A-C ALLIS-CHALMERS

A-5119







SAVIGLIANO

Hydrothermoelectric Station at Moncalieri (Turin, Italy) for A.E.M. Turin

●

Three single-phase transformers and spare unit for 40 MVA three-phase bank - with on-load tap changing device

●

One 5,5 MVA vertical generator - 107 rpm

●

One 5,5 MVA three-phase transformer

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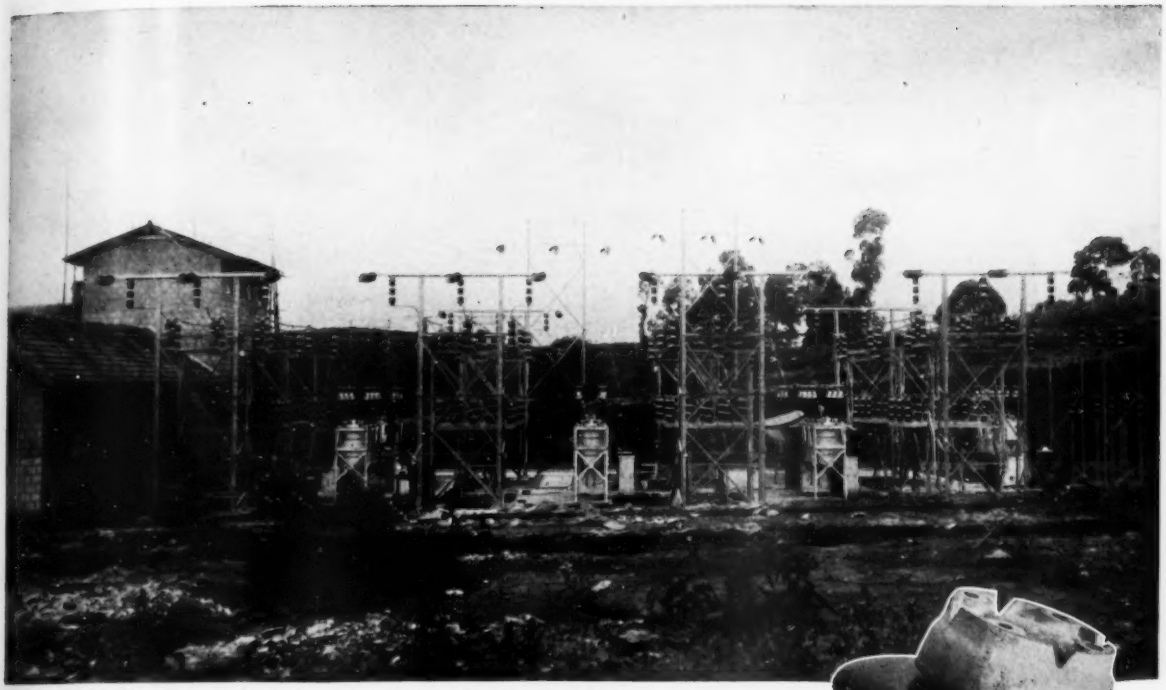
Works in Savigliano and Turin (Italy) Head Offices in Turin - Corso Mortara 4 - Phone 290481



(Photograph reproduced by courtesy of Messrs. Metropolitan Vickers Electrical Co. Ltd.)

The substation at Kothamangalam, Travancore, India, one of the 66kV substations on the Pallivasal project equipped with S.P.P. Post insulators type P.642.

S.P.P. POST INSULATORS

were used on all the 66kV outdoor switchgear on the Pallivasal Hydro Electric Scheme

STEATITE & PORCELAIN PRODUCTS LTD.

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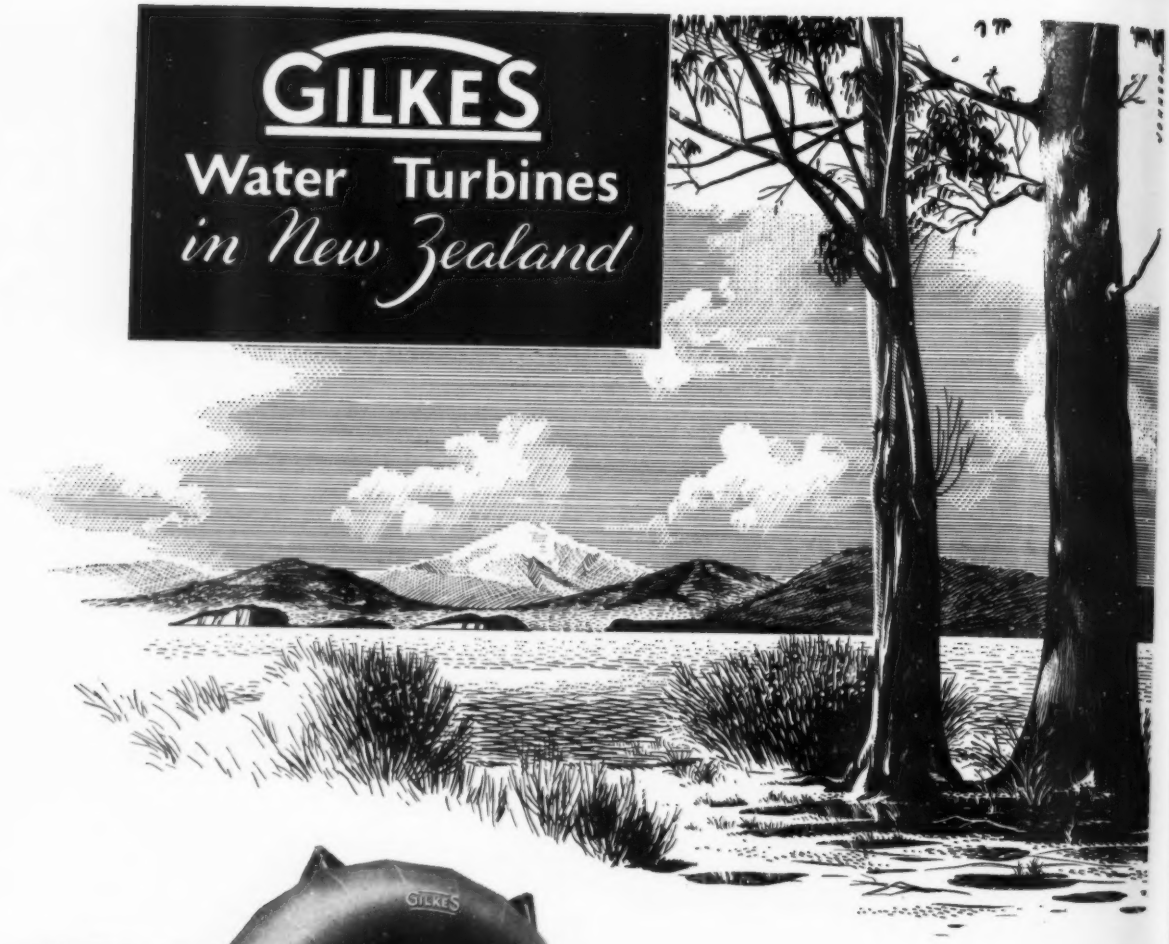
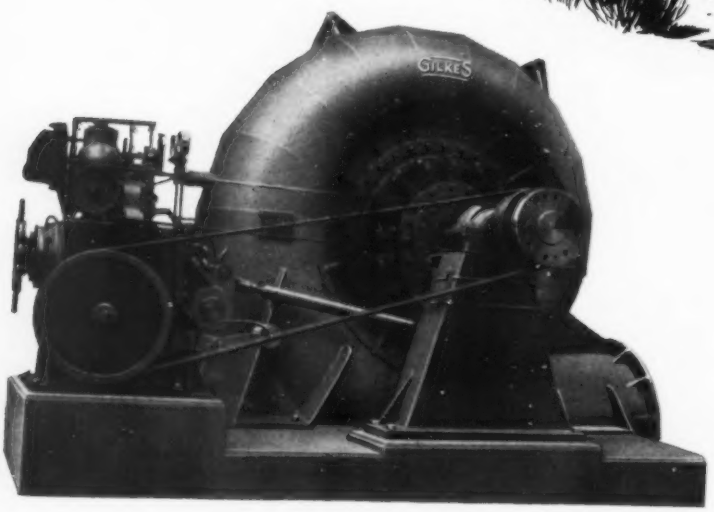
S.P.6

GILKES
Water Turbines *in New Zealand*





The illustration shows a Francis type water turbine supplied to the Taupo Town Board, North Island, New Zealand. It develops 1400 horsepower on 100 feet net head, and is controlled by an oil-pressure governor. The turbine casing is of welded steel and has a 45-inch bore inlet. A centralised lubrication system is fitted, enabling greasing to be carried out from one position.

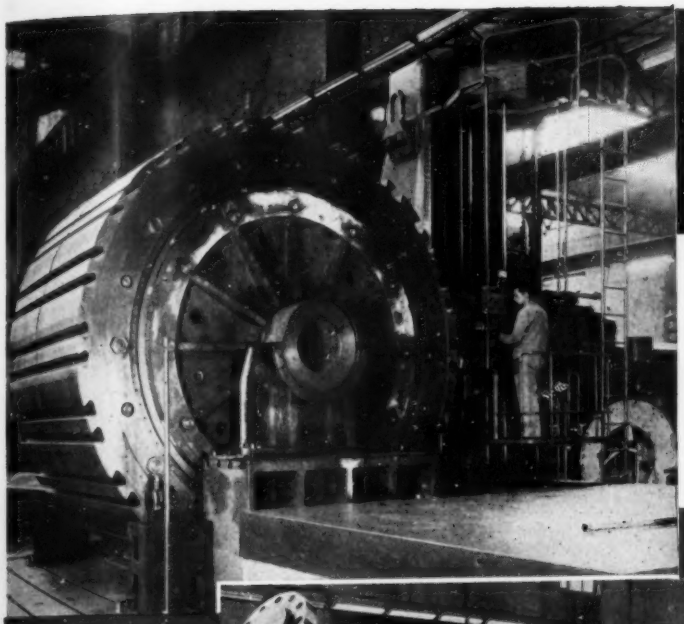
GILBERT GILKES & GORDON LTD

WATER TURBINE & PUMP MANUFACTURERS

KENDAL Telephone: Kendal 28 ENGLAND

London Office: CRAVEN HOUSE, KINGSWAY, LONDON W.C.2. Telephone: HOLBORN 3231/2

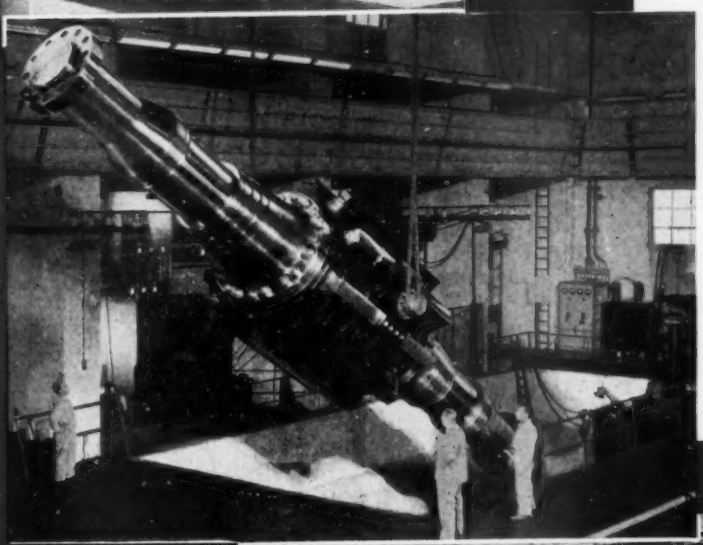
G56



Marelli

ERCOLE MARELLI & C. S.p.A.
MILAN (Italy)

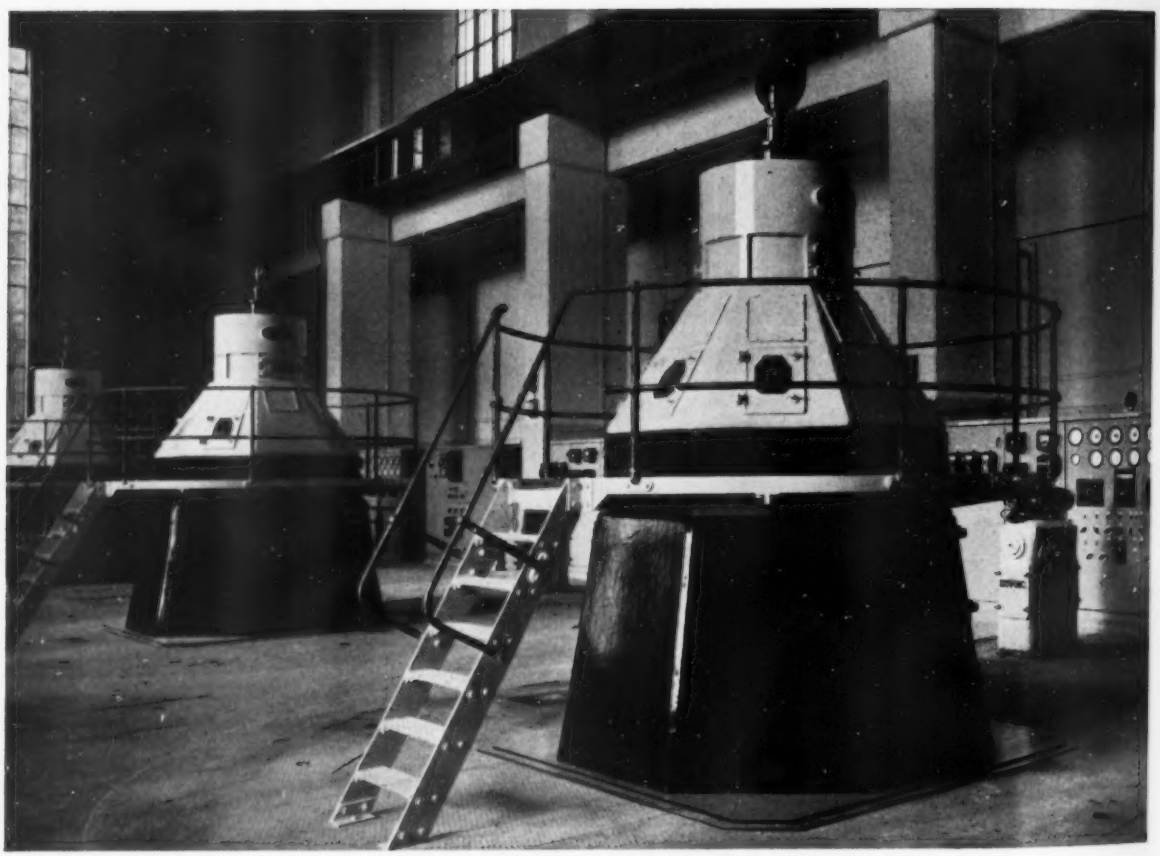
HYDRO-ELECTRIC EQUIPMENT



Rotor, shaft and stator for one of the two Water Wheel Alternators (110,000 kVA—13,800 Volts—300 r.p.m.—weight 650 tons) installed by Marelli in the Cimego Hydro-Electric Power Station of the Società Elettrica Bresciana (Italy). These alternators are believed to be the largest horizontal units yet built.

Highland water power

This is Errochty power station on the shore of Loch Tummel. It is the largest generating station in the Tummel-Garry Scheme of the North of Scotland Hydro-Electric Board, and houses three 25 MW vertical-shaft hydro-alternators built and installed by G.E.C. Auxiliary motors and most of the control gear in the station were also supplied by G.E.C.

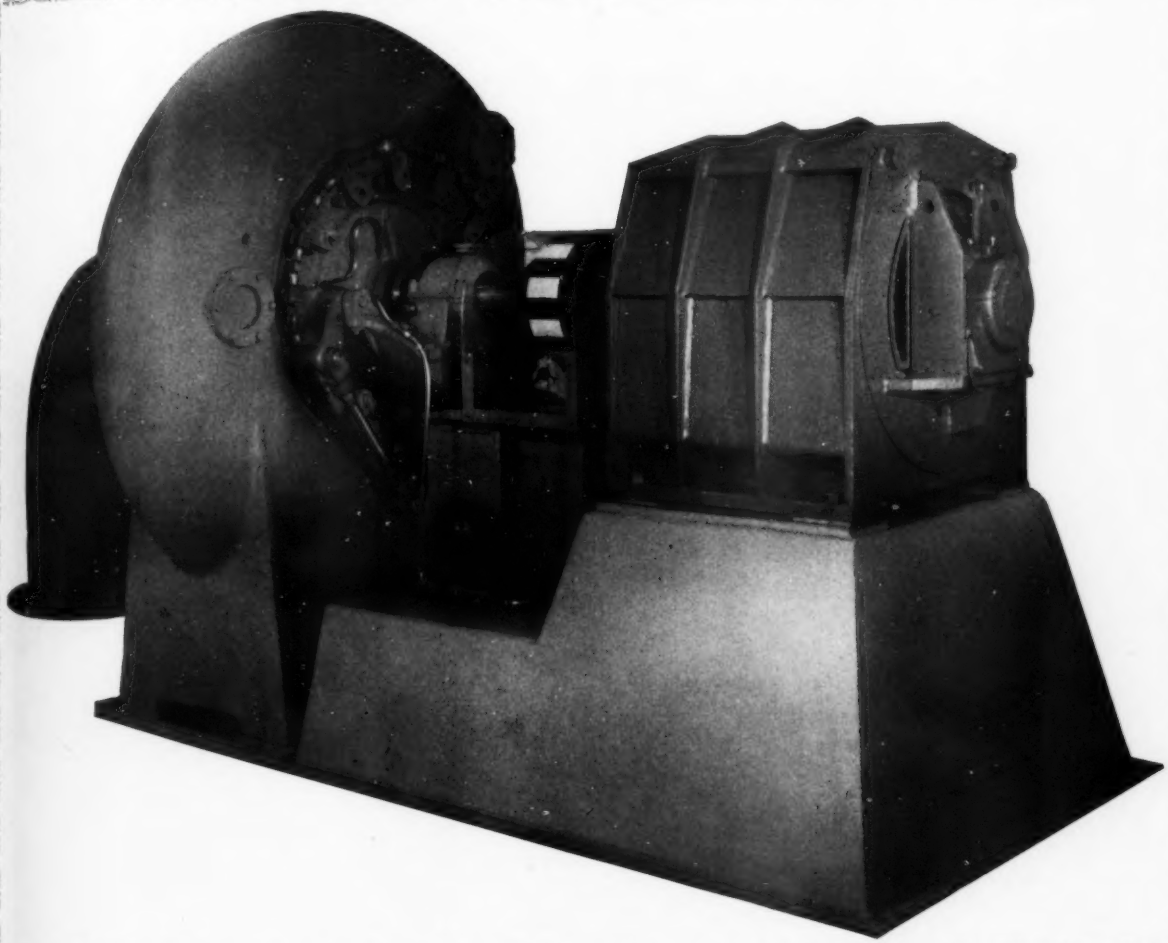


G.E.C.

HYDRO-ELECTRIC PLANT

THE GENERAL ELECTRIC CO. LTD · MAGNET HOUSE · KINGSWAY · LONDON · W.C.2

Form in Power



Induction Turbo-Generator

by ***ARMFIELD***

Illustration reproduced by kind permission of the North of Scotland Hydro-Electric Board. Consulting Engineers, Messrs. Merz and McLellan. Induction Generator, Messrs. Bruce Peebles & Co. Limited.

ARMFIELD

THE ARMFIELD HYDRAULIC ENGINEERING CO. LTD

RINGWOOD, HAMPSHIRE, ENGLAND *Phone: Ringwood 760 Grams: Hydraulics, Ringwood*

Complete Equipment for Water Power Plants

Turbines of the Francis, Kaplan and Pelton type for various heads and outputs, transformers, generators, outdoor and indoor switch-gear, control-rooms, etc. The World-renowned SKODA and CKD Trade-marks guarantee the first-class technical design and quality of equipment supplied by us. We give integral guarantees for complete deliveries. We shall be pleased to advise you in all your problems connected with the projection of water power plants.

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FOREIGN TRADE CORPORATION FOR EXPORT OF COMPLETE INDUSTRIAL PLANTS

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round-the-clock reliability

Under the toughest conditions in all parts of the world EIMCO Rocker-shovels are working continuously on three shifts throughout the 24 hours.

EIMCO 621 Crawler type Rockershovels will load a 4½ yd. dumper in two minutes.

Powered by electricity or compressed air they are one of a wide range of machines maintaining phenomenal outputs of every type of mining and tunnelling project.

The robust construction which ensures such reliability and extended life has enabled EIMCO to maintain its lead in all fields covered by its equipment.

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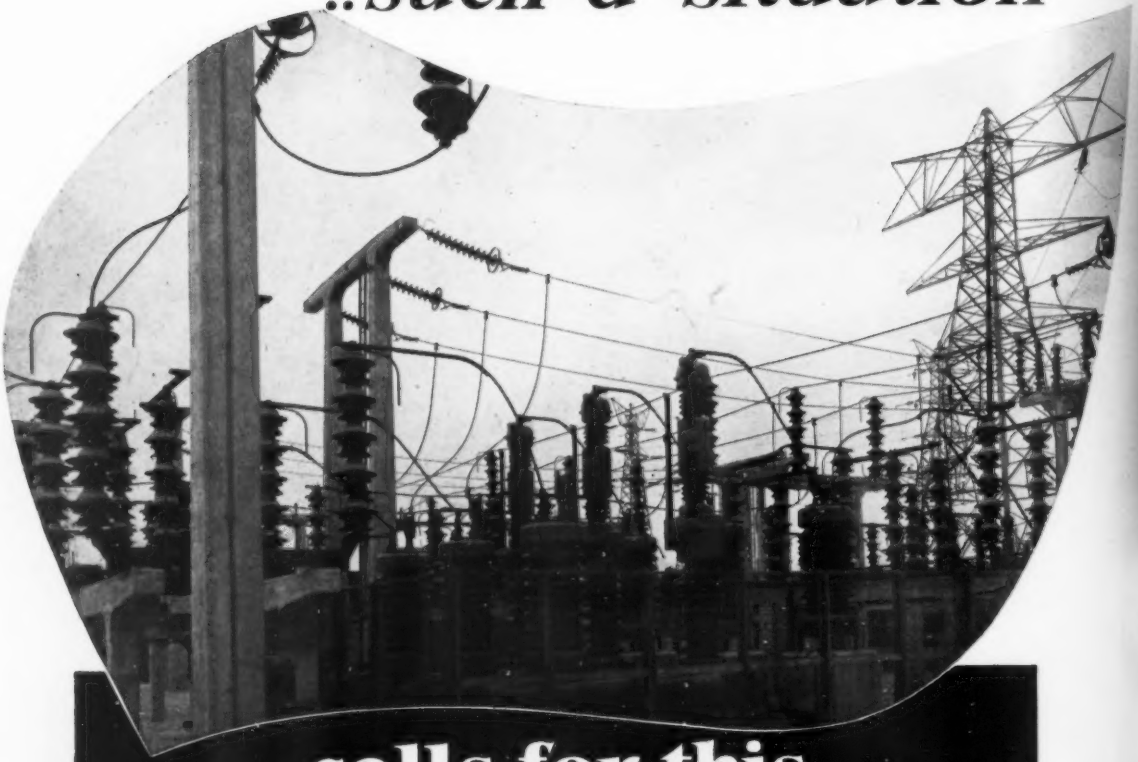
London Office: PRINCES HOUSE, PICCADILLY, W.1. GROsvenor 2184

..such a situation



calls for this...

Thoroughly proven in efficiency, reliability and economy of operation, Miniature Direct Wire remote control systems by *Standard* are serving electricity undertakings at home and overseas, greatly simplifying the central control of electricity generation and distribution networks.

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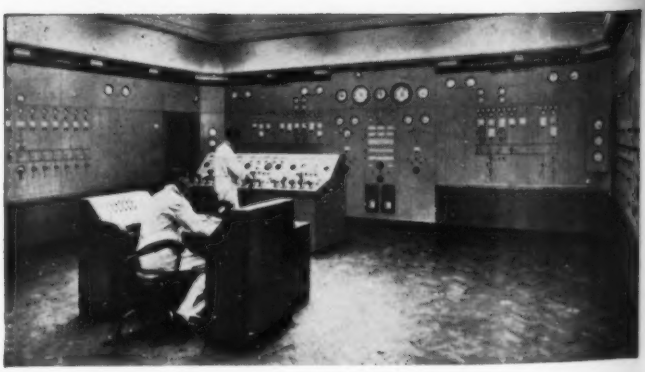

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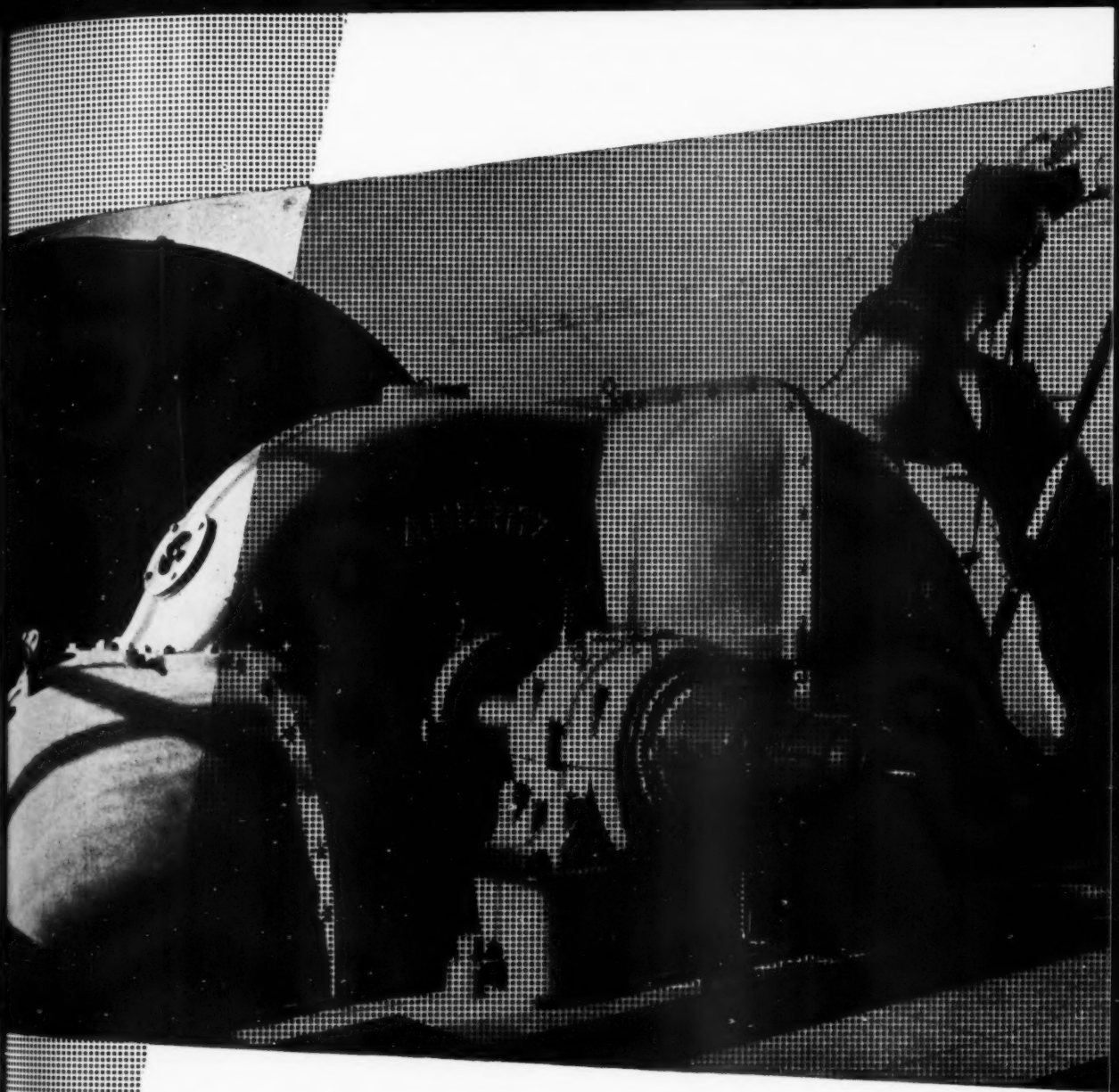
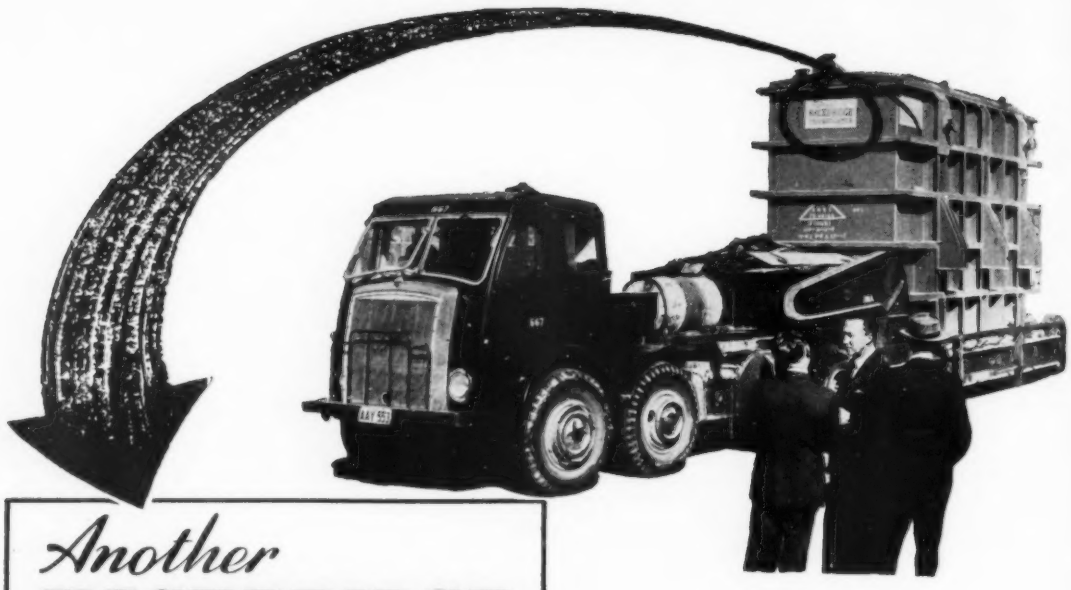


Water Turbines

MASCHINENFABRIK
ANDRITZ
ACTIENGESELLSCHAFT
Graz-Andritz, Austria



Another

HACKBRIDGE TRANSFORMER

FOR SERVICE OVERSEAS

MONTH after month large Hackbridge transformers leave the Works for destinations extending to the most distant parts of the world. The illustrations show the arrival and installation of one of five 30,000 kVA 132/33 kV type ON/OB Hackbridge transformers for the Electricity Commission of New South Wales.

Over 22 million kVA of Hackbridge transformers have been manufactured, including some of the world's largest units.

HACKBRIDGE TRANSFORMERS

Made in Britain by

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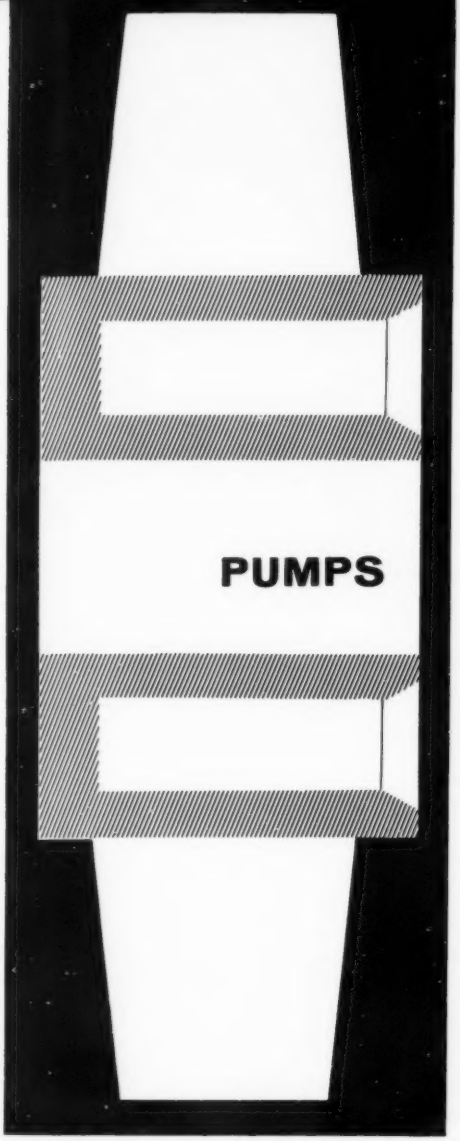
OVERSEAS REPRESENTATIVES.—ARGENTINA : H. A. Roberts & Cia., S.R.L., Buenos Aires. AUSTRALIA : Hackbridge and Hewittic Electric Co. Ltd., 171 Fitzroy Street, St. Kilda, Victoria; N.S.W.: Queensland: W. Australia: Elder Smith & Co Ltd.; S. Australia: Parsons & Robertson Ltd. BELGIUM & LUXEMBOURG: M. Dorfman, 5 Avenue des Phalenes, Brussels. BRAZIL: Oscar G. Mors, Sao Paulo. CANADA : Hackbridge and Hewittic Electric Co. of Canada Ltd., Montreal; The Northern Electric Co. Ltd., Montreal, etc. CEYLON: Envee Ess Ltd., Colombo. CHILE: Ingenieria Electrica S.A.C., Santiago. EAST AFRICA: Gerald Hoe (Lighting) Ltd., Nairobi. EGYPT : Giacomo Cohenca Fils, S.A.E., Cairo. FINLAND : Sähkö-ja Koneliike O.Y. Hermes, Helsinki. HOLLAND : J. Kater E.I., Ouderkerk a.d. Amstel, Amsteldijk Noord, 103c. INDIA: Steam & Mining Equipment (India) Ltd., Calcutta; Easun Engineering Co. Ltd., Madras, I. IRAQ: J. P. Bahoshy Bros. Baghdad. MALAYA, SINGAPORE & BORNEO : Harper, Gilfillan & Co. Ltd., Kuala Lumpur. NEW ZEALAND : Richardson, McCabe & Co. Ltd., Wellington, etc. PAKISTAN : James Finlay & Co. Ltd., Karachi. SOUTH AFRICA : Fraser & Chalmers (S.A.) (Pty.) Ltd., Johannesburg. CENTRAL AFRICAN FEDERATION: Fraser & Chalmers (S.A.) (Pty.) Ltd., Salisbury, etc. THAILAND: Vichien Phanich Co. Ltd., Bangkok. TRINIDAD & TOBAGO : Thomas Peake & Co., Port of Spain. TURKEY : Dr. H. Salim Öker, Ankara. URUGUAY: H. A. Roberts & Cia., S.A.U., Montevideo. U.S.A.: Hackbridge & Hewittic Electric Co. Ltd., P.O. Box 234, Pittsburgh 30, Pennsylvania.



FOR PUMPING PLANTS
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FOR CIVIL - AGRICULTURAL
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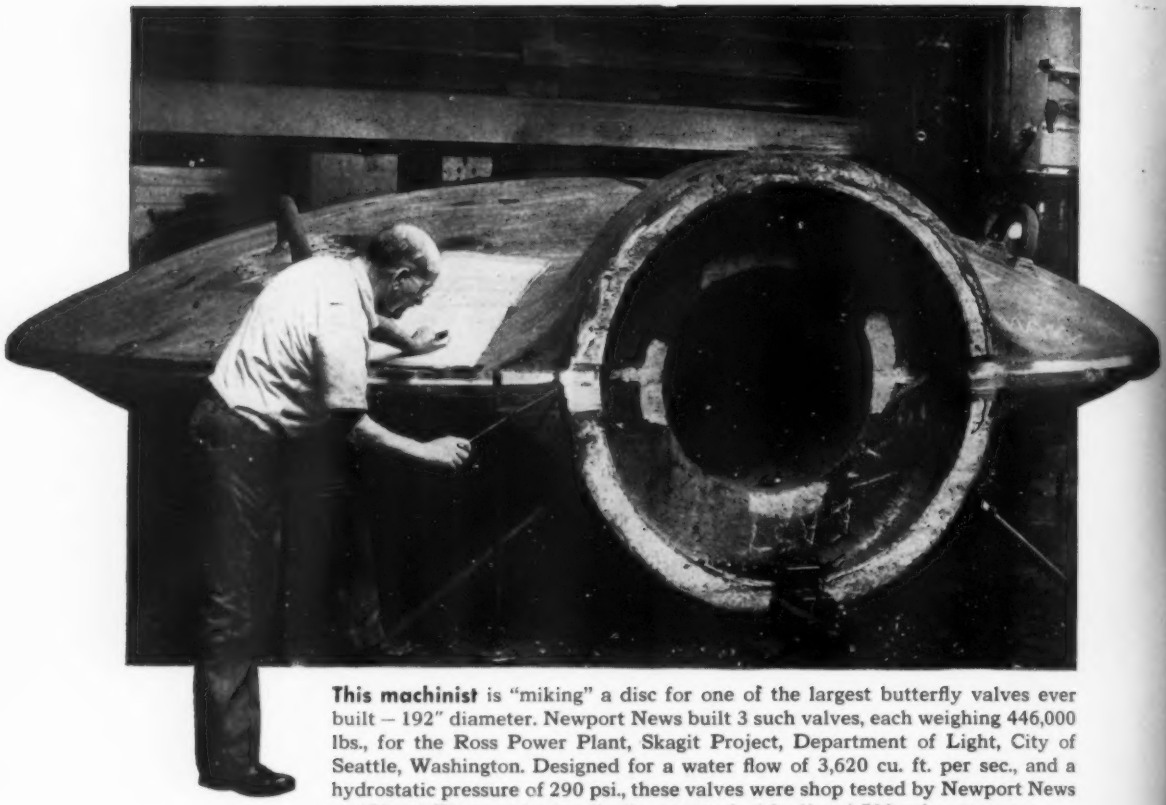


This machinist is "miking" a disc for one of the largest butterfly valves ever built – 192" diameter. Newport News built 3 such valves, each weighing 446,000 lbs., for the Ross Power Plant, Skagit Project, Department of Light, City of Seattle, Washington. Designed for a water flow of 3,620 cu. ft. per sec., and a hydrostatic pressure of 290 psi., these valves were shop tested by Newport News at 450 psi. They are hydraulically operated with oil at 1,500 psi. pressure.

Birth of a **200-ton** Butterfly

This disc for a 16-foot butterfly valve reflects two basic advantages of Newport News fabrication...

First, it exemplifies the *careful attention* Newport News craftsmen give to every detail. And secondly, it attests to the *quality* with which Newport News produces in massive equipment for public utilities and allied industries... due to Newport News' high integration of skill and production facilities.

Additional advantages accrue to customers from extensive work conducted in Newport News' testing laboratories on problems related to water power equipment.

Avail yourself of the engineering talent, along with the specialized production techniques and the skill of Newport News craftsmen operating vast steel fabricating shops, five huge machine shops, drop forging and die facilities along with acres of brass, iron and steel foundries.

Let us bid on equipment for your present or future projects. If you are not familiar with the way Newport News can help you, write for our illustrated booklet entitled "Water Power Equipment" ...it's yours for the asking.

NEWPORT NEWS

Shipbuilding and Dry Dock Company

Newport News, Virginia

Storage Pumps

for hydro-electric power schemes

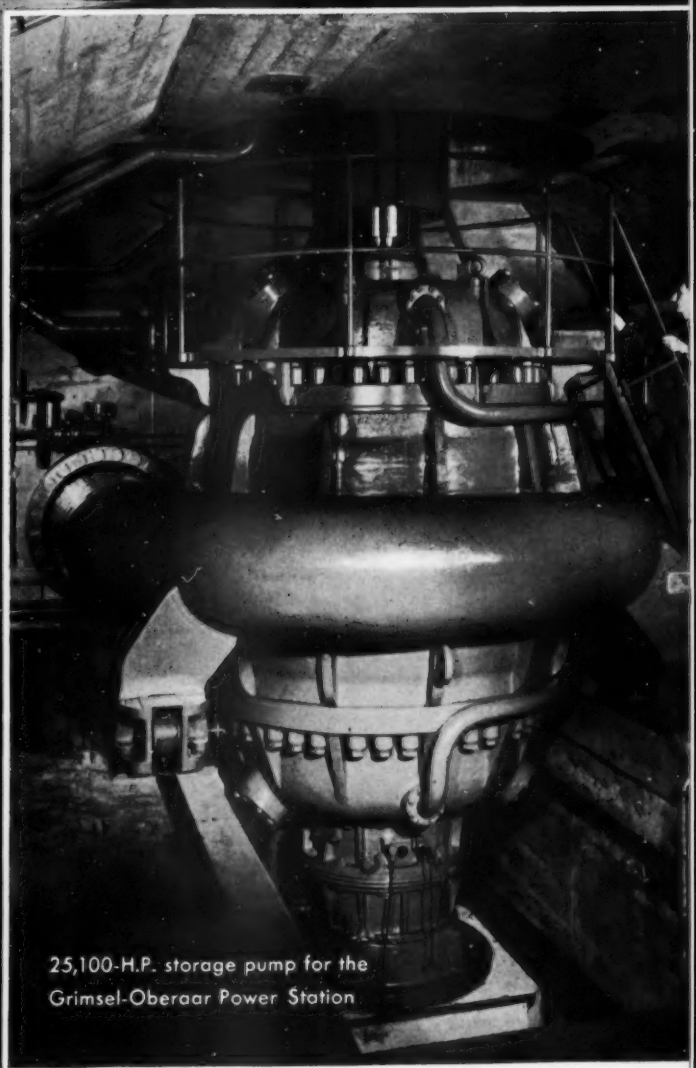
The following high-lift storage pumps are at present in hand: –

two pumps for
Reisseck Power Station, Austria
(each for 6,000 g. p. m., head 3,510 ft. speed 1,500 r. p. m., input 7,550 H. P., final pressure 4,085 ft.)

one pump for
Lünersee Power Station, Austria
(discharge 49,250 g. p. m., head 3,182 ft., speed 750 r. p. m., input 54,750 H. P.)

one pump for
Motec Power Station, Switzerland
(discharge 43,050 g. p. m., head 2,060 ft., speed 750 r. p. m., input 30,400 H. P.)

Lake Oberaar, 7,550 ft. above sea level, in the Bernese Oberland, Switzerland



25,100-H.P. storage pump for the Grimsel-Oberaar Power Station

SULZER BROTHERS LIMITED, WINTERTHUR, SWITZERLAND
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(INCORPORATING HATHORN, DAVEY & COMPANY, LTD.)

MAXWEHR POWER STATION OF LANDSHUT/ISAR
equipped with 2 Kaplan turbines and cabinet-type governors supplied by

J. M. VOITH GMBH, of Heidenheim/Brenz (Germany)

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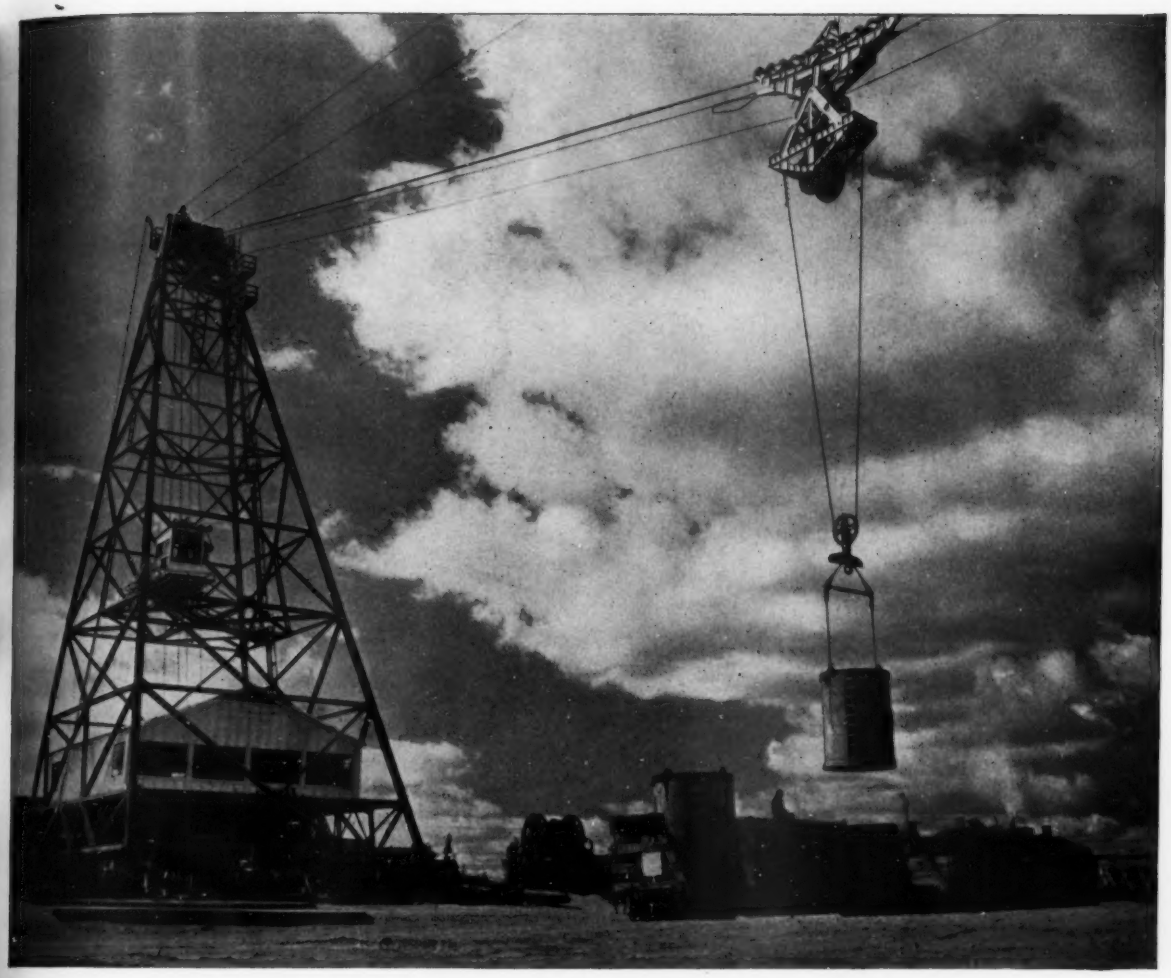
GRENOBLE-FRANCE



20 ton 'TRAVELIFT' Cableway handling 8 cu. yd. capacity bottom discharge concreting bucket.

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BRECO — Sole manufacturers of 'Travelift' Cableways, outside the North American Continent. TRAVELIFTS are especially suited to high speed heavy construction work.

Literature available on request.

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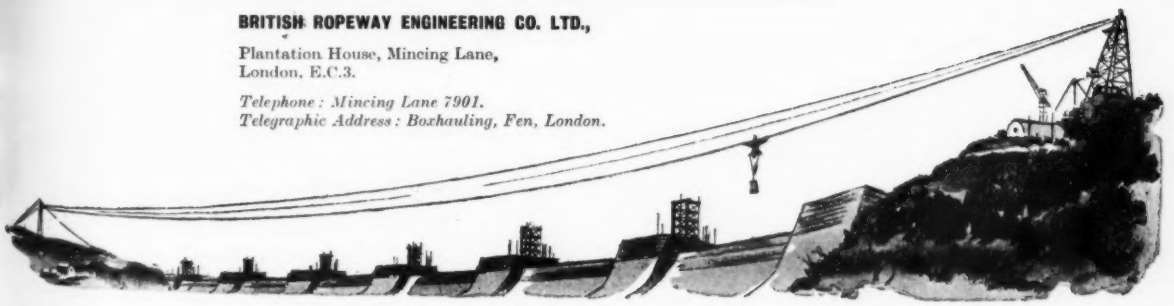
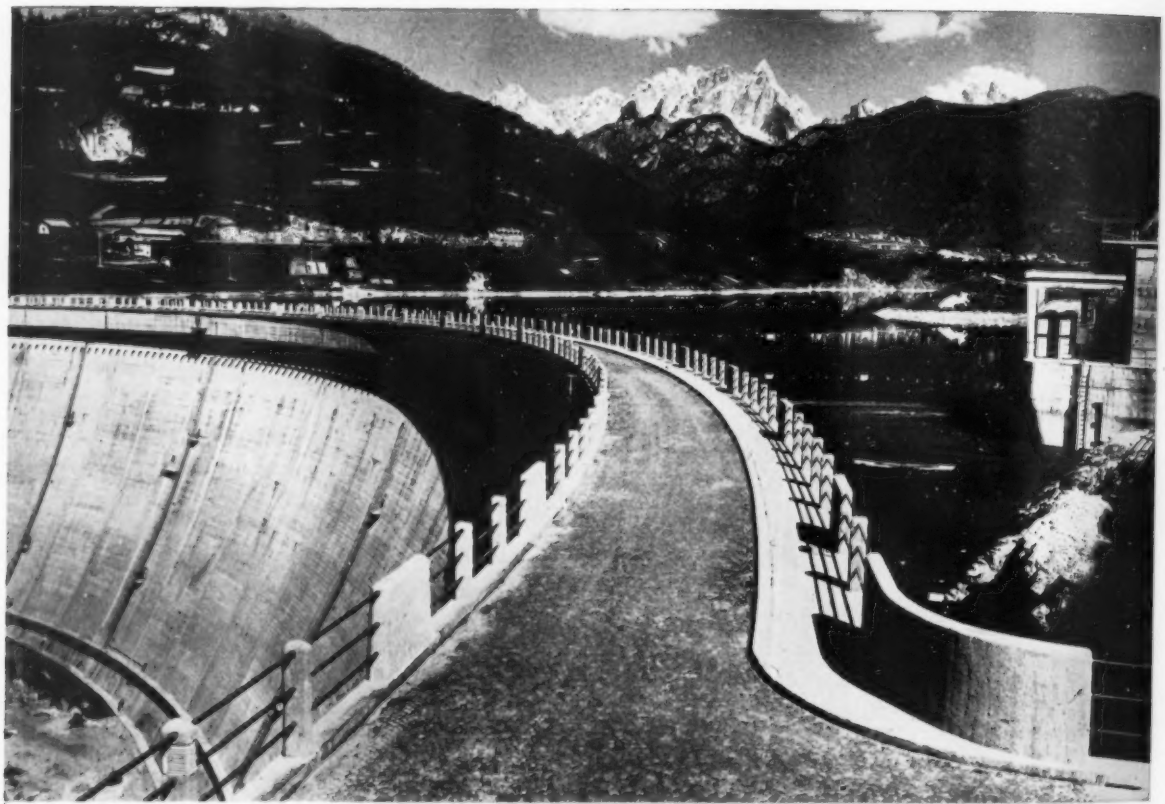
Plantation House, Mincing Lane,
London, E.C.3.

Telephone: Mincing Lane 7901.
Telegraphic Address: Boxhauling, Fen, London.



ITALY'S BIG WATER-POWER PLAN IS TAKING SHAPE



The Pieve di Cadore Dam in the Dolomites. This forms a reservoir of over 2 million cubic feet of water. The dam is 370 ft. high with a length across the top of 1,015 ft. Developed by Società Adriatica di Elettricità, SADE.

The Dolomites and the Appenines are taking on a new role. One by one their fast-flowing mountain rivers are being harnessed to provide the whole of Italy with a cheap, abundant supply of power. Under an immense water-power development programme that has been going on since 1948, dams have been constructed, tunnels driven under mountain ranges and power houses installed above and below ground. The results have been impressive, indicative of the speed with which the plan is taking shape. The latest available figures, those of 1955, show Italy's installed hydro-electric capacity at over 9 million kilowatts.

Two Atlas Copco drills engaged on benching operations for the foundations of the Val Martello Dam. Contractors: Ing. Torno.

Atlas Copco supply 85 % of the drills

In 1950 Atlas Copco rock drills and Sandvik Coromant steels were introduced for the first time into Italy. In that year they accounted for 10 per cent of the drilling equipment engaged on the hydro-electric projects. As on many other giant construction projects throughout the world the performance of this lightweight drilling unit was outstanding, resulting in its wide-scale adoption. *By 1955 over three-quarters of the rock drills working on Italian hydro-electric projects were Atlas Copco machines and nearly half the steels, Sandvik Coromants.*

Thirty million cu. ft. of rock a year

For the past five years Atlas Copco drills and Sandvik Coromant steels have been responsible for the excavation of 30 million cubic feet of rock *per year* on Italian hydro-electric projects. Considering the small-sized sections of Italian tunnels, this amount of rock means miles and miles of tunnelling a year. Other Atlas Copco equipment in wide use on Italian power projects includes mine loaders and air compressors.

The world's leading drilling unit

On hydro-electric projects from India to Norway, Australia to Brazil, Atlas Copco drills and Sandvik Coromant steels are in operation. These drills and steels were developed to work together as a lightweight drilling unit. Since its introduction in the early 'forties it has extensively replaced the heavy bar-rigged drifter. Today, Atlas Copco drills and Sandvik Coromant steels are the world's most widely-used pusher leg drills and integral steels, responsible for the drilling of no less than one billion feet annually.

More drills in action at the face

Atlas Copco light rock drills are compact, *one-man* machines. That enables you to put *more* drills into action at the face at one and the same time. More drills mean *faster* times each round and, because they're one-man machines, a reduction—in most cases—of total shift crews by at least a third. At the same time the original capital outlay and general maintenance costs are far lower than for those of heavy equipment. So, if you want to do the job faster, and at lower cost, the Atlas Copco light rock drill is *your* machine.

Extra-tough Sandvik Coromant steels

At the drilling end of Atlas Copco rock drills you'll find Sandvik Coromant steels. Their high, uniform quality guarantees a constant rate of progress with a minimum of costly and troublesome interruptions during drilling due to steel failures. Sandvik, to maintain this never-varying drill steel quality, control every phase of production—from the mining of iron ore, processing of wolfram ore, to the final tungsten-carbide-tipped steels used throughout the world wherever Atlas Copco drills are in action.

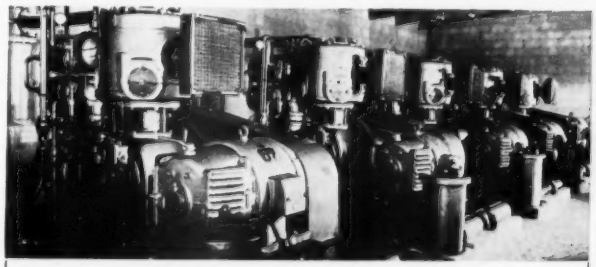
Drilling Advisory Service

Atlas Copco possess their own Project Department, whose job is to plan drilling operations and to advise on mining and tunnelling techniques. Their expert services are at the disposal of contractors and mining engineers without obligation.

The Atlas Copco Group puts compressed air to work for the world. It is the largest group of companies specializing solely in the development and manufacture of compressed air equipment. It embraces Atlas Copco companies or agents manufacturing or selling and servicing Atlas Copco equipment in ninety countries throughout the world. For further information about the equipment featured please contact your nearest Atlas Copco Company or Agent. There are Atlas Copco companies in Wembley (England); Paris; Rotterdam; Milan; Brussels; Copenhagen; Oslo; Stockholm; Essen; Madrid; Istanbul; Nicosia (Cyprus); Casablanca; Benoni (Transvaal S.A.); Ndola (N. Rhodesia) or Belmont (S. Rhodesia); Montreal; Paterson N.J. and San Carlos Cal. (U.S.A.); Torreon (Mexico); Auburn (N.S.W. Australia); Wellington; Rio de Janeiro; Santiago de Chile; Lima. If you have difficulty in contacting your local Atlas Copco organization please write to Atlas Copco AB, Stockholm 1, Sweden.

85% of all rock drills at work on Italian power projects are Atlas Copco machines. Nearly half the steels, Sandvik Coromants. Here are some in action on a 10-mile tunnel for the Avisio project north of Trento. The drills were powered by several Atlas Copco AR compressors. Contractors: Ing. S. Quadrio Curzio.

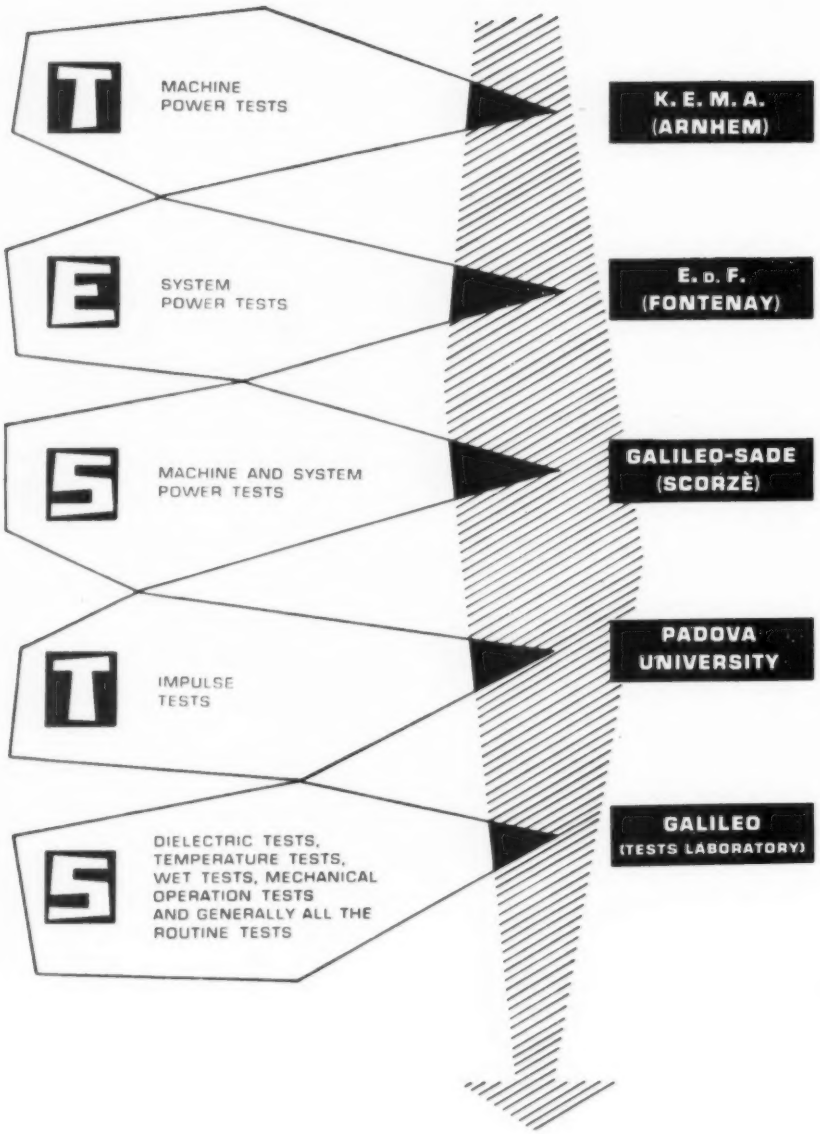
An Atlas Copco LM 100 mine loader mucking-out on an Italian tunnelling scheme. Contractors: Geom. P. Tabacchi.



Five Atlas Copco AR 3 compressors installed on the site of big excavation operations in Sardinia. Contractors: SOGENE.

THE **Atlas Copco** GROUP OF COMPANIES

Manufacturers of Stationary and Portable Compressors, Rock-Drilling Equipment, Loaders, Pneumatic Tools and Paint-Spraying Equipment



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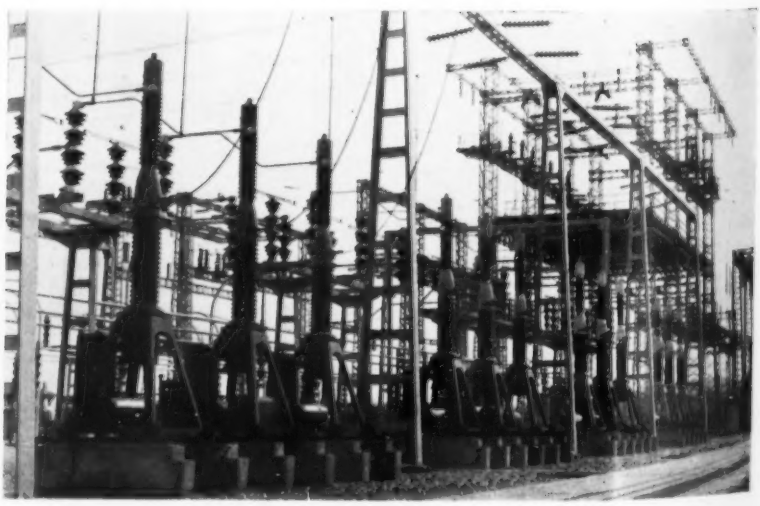
One French station of the Electricite de France equipped with Galileo Circuit Breakers for 150 kV.



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The Merila Barrage is part of the Low Tana Hydro Electric Development in Kenya, which has been designed and constructed by Balfour Beatty for the East African Power and Lighting Co. Ltd.

The photograph of part of the barrage, which diverts water into the headrace tunnel, shows one of the 37′ 6″ span automatic control gates starting to open.

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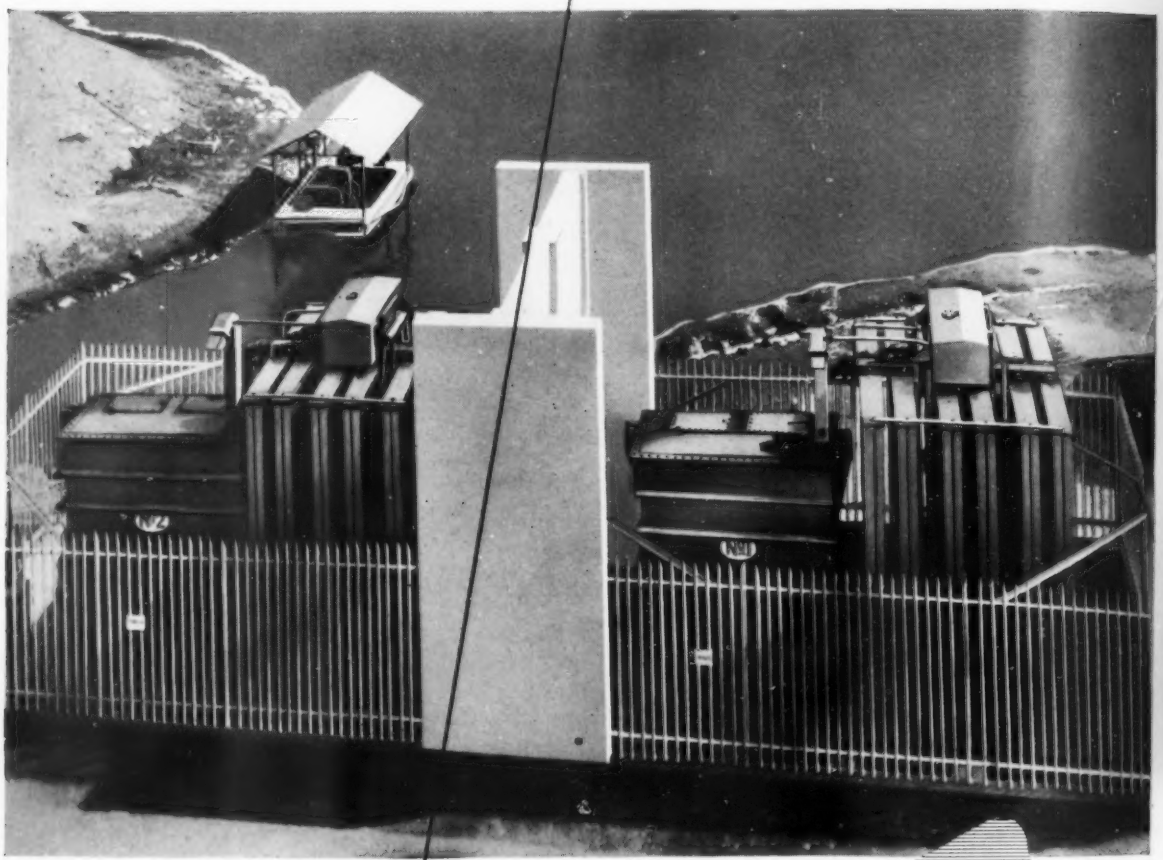

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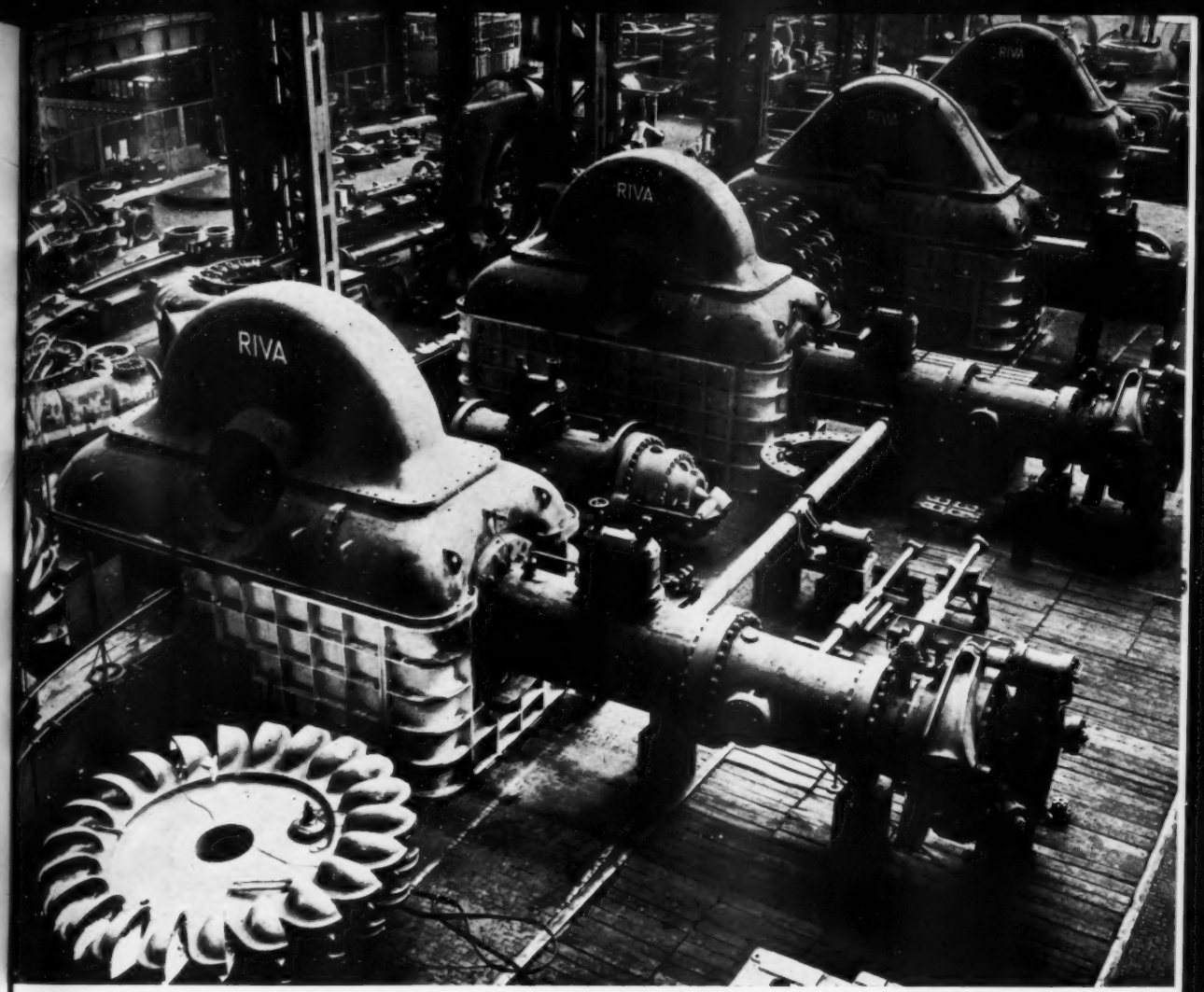

Main units actually in course of construction in our works :

PELTON : 2 Turbines each of 150,000 h.p. for Cimego Power Station, Italy.
2 Turbines each of 110,000 h.p. for Premadio Power Station, Italy.
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3 Turbines each of 45,000 h.p. for Hospitalet Power Station, France.

FRANCIS: 2 Turbines each of 80,000 h.p. for Somplago Power Station, Italy.
1 Turbine of 24,000 h.p. for Merdj-ez-Erraguène Power Station, Algeria.

KAPLAN : 1 Turbine of 35,000 h.p. for La Penna Power Station, Italy.
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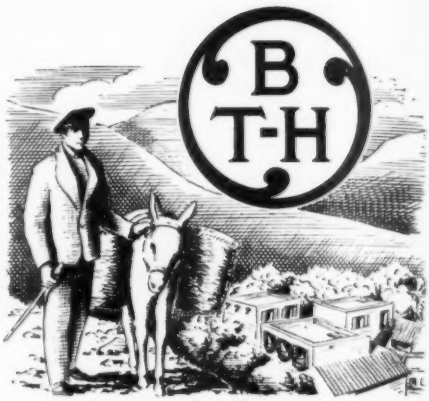
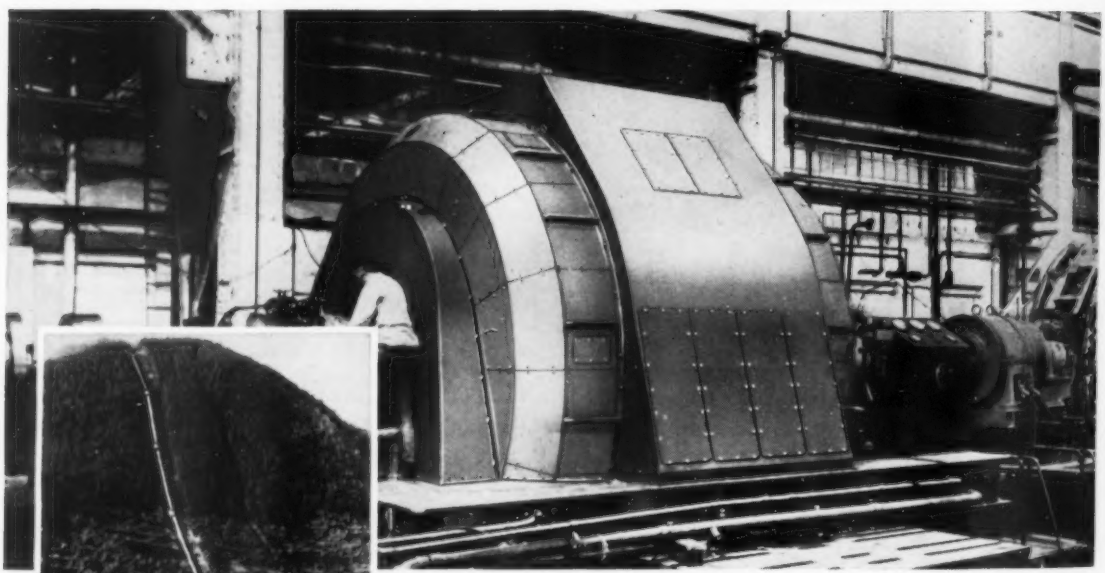
Power for Spain by

Many of the rivers of Spain and France rise in the High Pyrenees. Their waters are harnessed to supply electric power for railways, for industry and for the domestic supply of the surrounding countryside. Here, at Artias, where the River Garonne leaves Spain for its long flow through France, Sociedad Productora de Fuerzas Motrices, S.A. have built a new power station. It is 3,700 ft. above sea level, and in it BTH equipment is once again used to help harness the power of natural resources.





One of the two BTH generators on test at Rugby Works.

Two 42,500-kVA, 600-r.p.m., 11-kV generators have been supplied by BTH, each driven by two single-jet Pelton turbines supplied by Ets Neyrpic, Grenoble, one wheel being overhung from each end of the generator shaft. These turbines operate under a head of 2,600 ft.

General view of the power station and the penstock.

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The inset photograph shows a "Goliath" crane supplied by us to Messrs. Parkinson Howard Limited for their work on Tema Harbour in the Gold Coast. The Consulting Engineers on the Tema Harbour project are Sir William Halcrow & Partners Limited.

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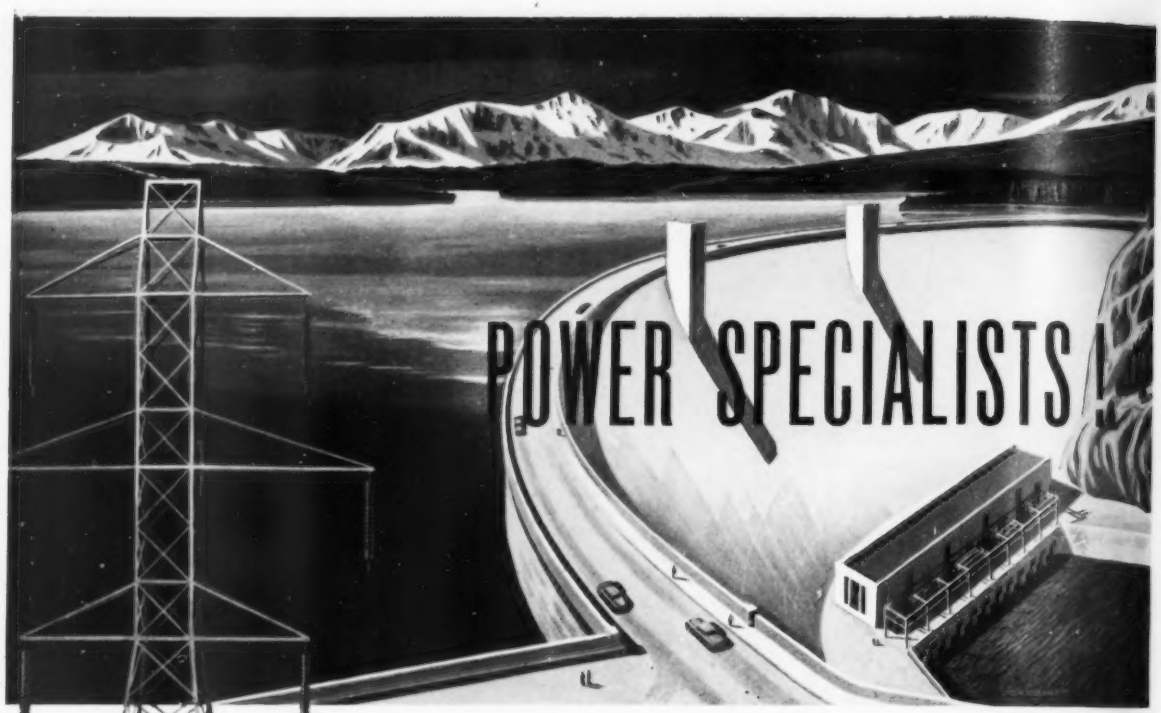

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Behind every Kuljian project lie the combined skills and experience of a complete staff of internationally recognized experts in every phase of water resource development. No matter where *your* next project might be, The Kuljian Corporation is fully prepared to undertake efficiently all phases of design, engineering, and construction supervision to help bring about the quick, economical solution to your specific problem.

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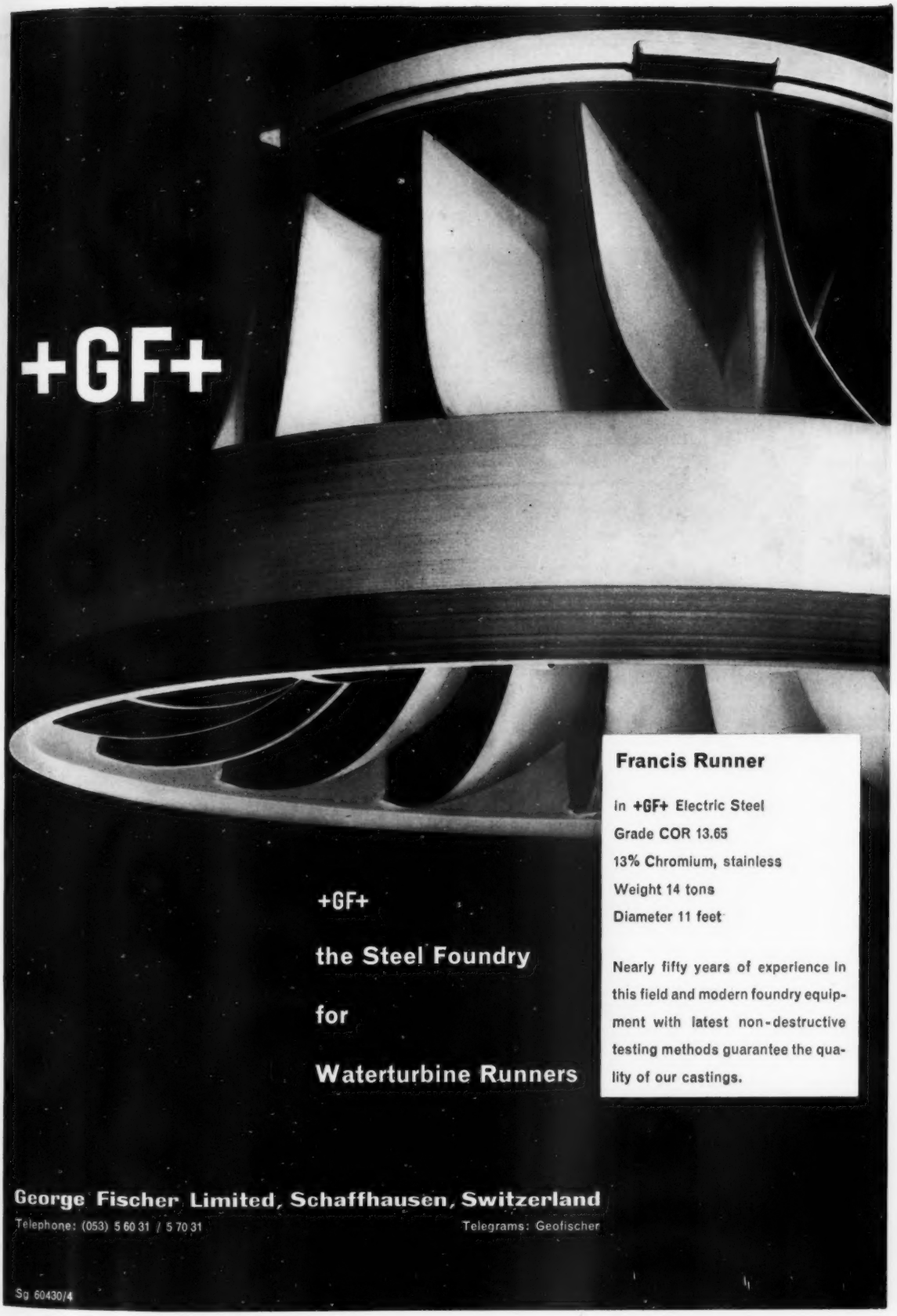
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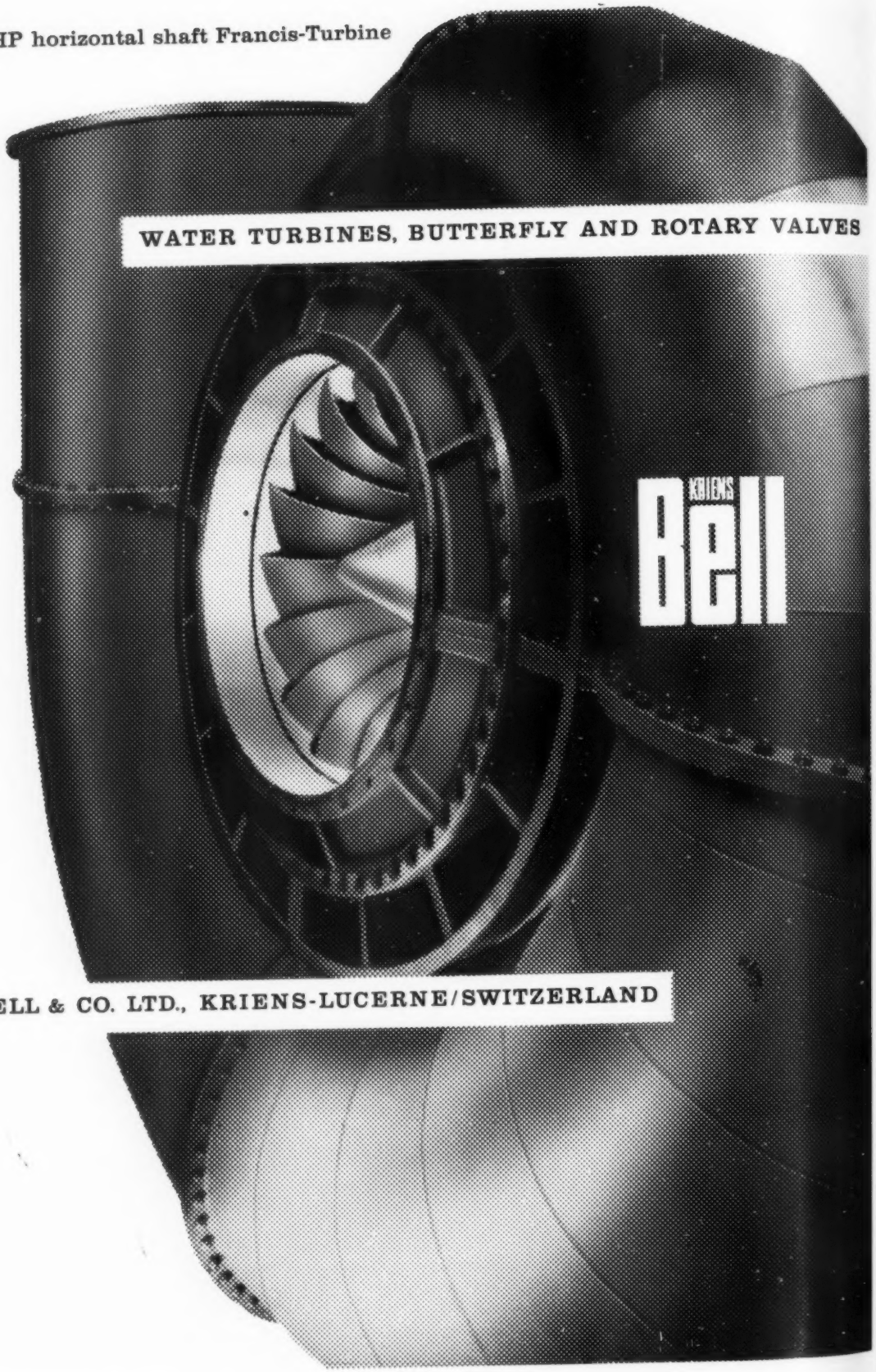

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Over 6,000 ft. a month was the record breaking rate at
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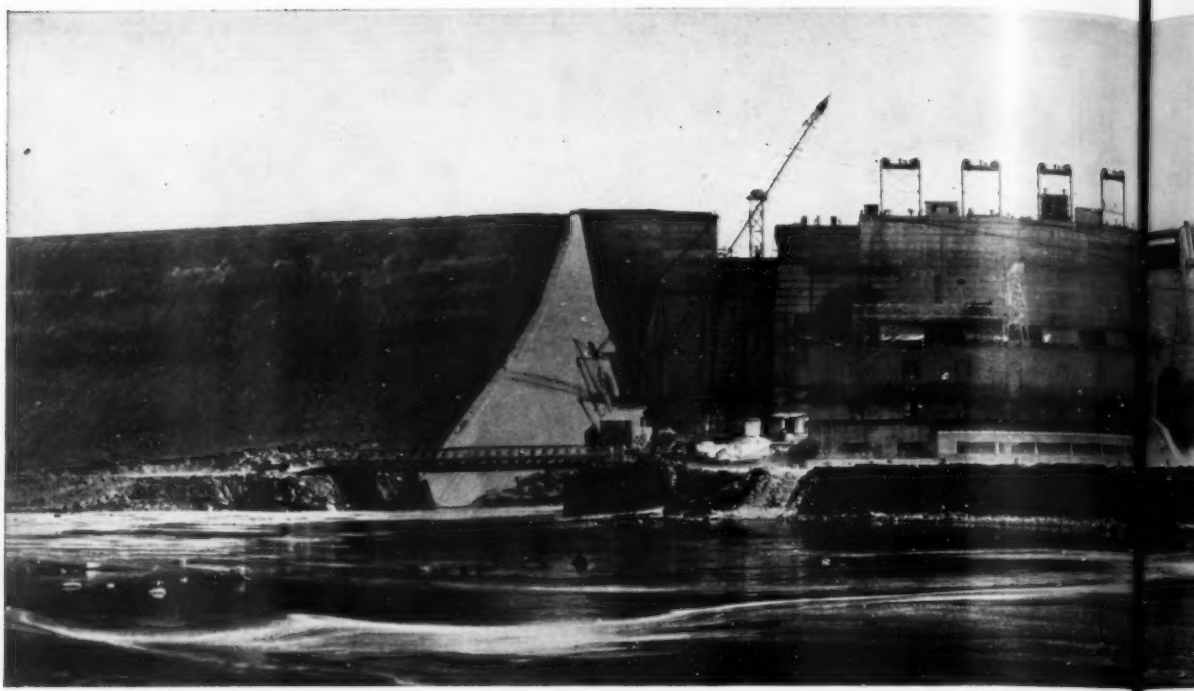


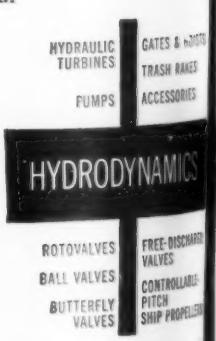
SMS-FRANCIS TURBINES AT LITTLETON DEVELOPMENT TO

GENERATE PEAK POWER

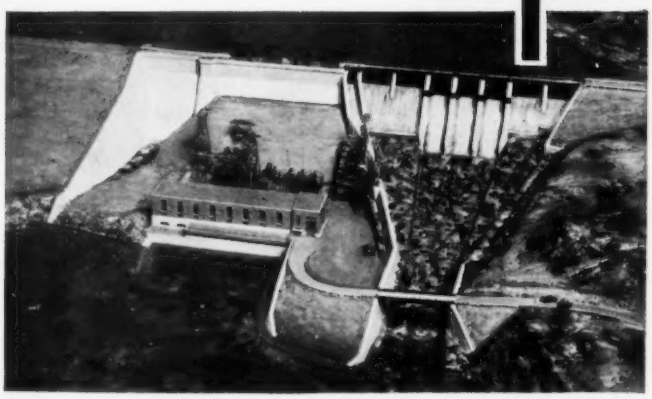
To meet rapidly increasing demands within the New England Electric System's area, Moore Station near Littleton, New Hampshire, will soon go on the line delivering peak load power. Rated at 150,000 kw, this new hydro plant is the third and last on the Fifteen Mile Falls stretch of the Connecticut River. Including the Comerford and McIndoes Stations immediately downstream, this will give a total capacity of 310,000 kw in a river fall of 367 feet at this location. Thus the largest of New England's rivers becomes one of the most highly developed streams of its size.

All three of the Fifteen Mile Falls plants are powered by SMS turbines. The four Littleton units are the vertical Francis type, each rated at 56,400 HP under a 150-foot head. SMS also provided four 18-foot x 24-foot fixed wheel intake gates for operation with an 84-foot head on the sill of the gate frame. The gates are designed for closing under full discharge and opening under balanced hydraulic conditions.

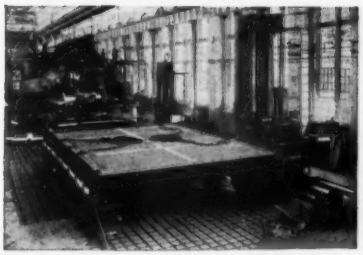
These three plants, with both SMS-Francis and Kaplan turbines as well as accessories, illustrate S. Morgan Smith's ability to handle the needs of any hydro project. Over three quarters of a century's experience in hydraulic design and manufacture stand behind SMS equipment. For full information, write S. Morgan Smith Company, York, Pennsylvania.



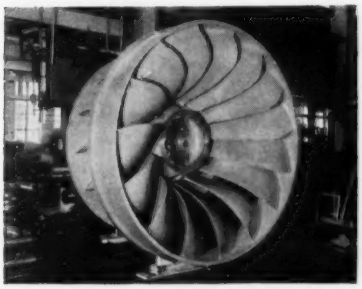
HYDRODYNAMICS



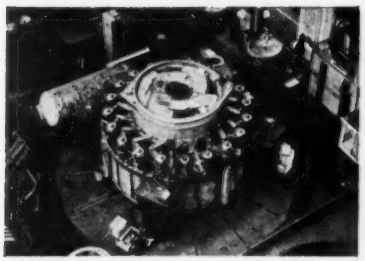
Looking upstream (top photo) across the tailrace area, the SMS-Fixed Wheel Intake Gate on Unit #3 can be seen being lowered into position atop the dam. Lower photo shows a scale model of the complete development.



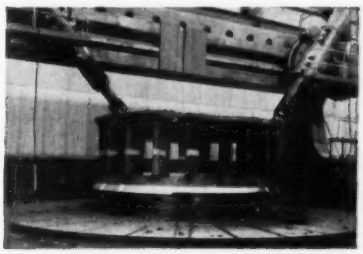
Two halves of a gate have been assembled and aligned on a 7-inch bar horizontal boring mill. SMS bores wheel axle holes in this manner to assure accurate alignment within close tolerances.



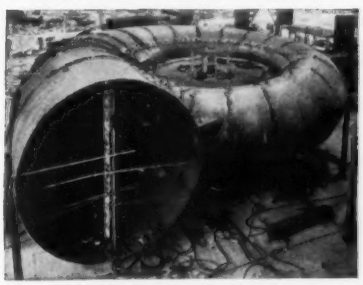
Unit #3's runner, completed and ready for shipment.



Complete distributor assembly is carefully shop-checked prior to dismantling for shipment.



Here a 40-foot vertical boring mill machines riveting flanges on a cast-steel stay ring.



The 198-inch diameter riveted plate steel spiral case (with riveted cover plates) for Unit #1, taken during assembly at SMS Plant #2.

S. MORGAN SMITH

AFFILIATE: S. MORGAN SMITH, CANADA, LIMITED, TORONTO

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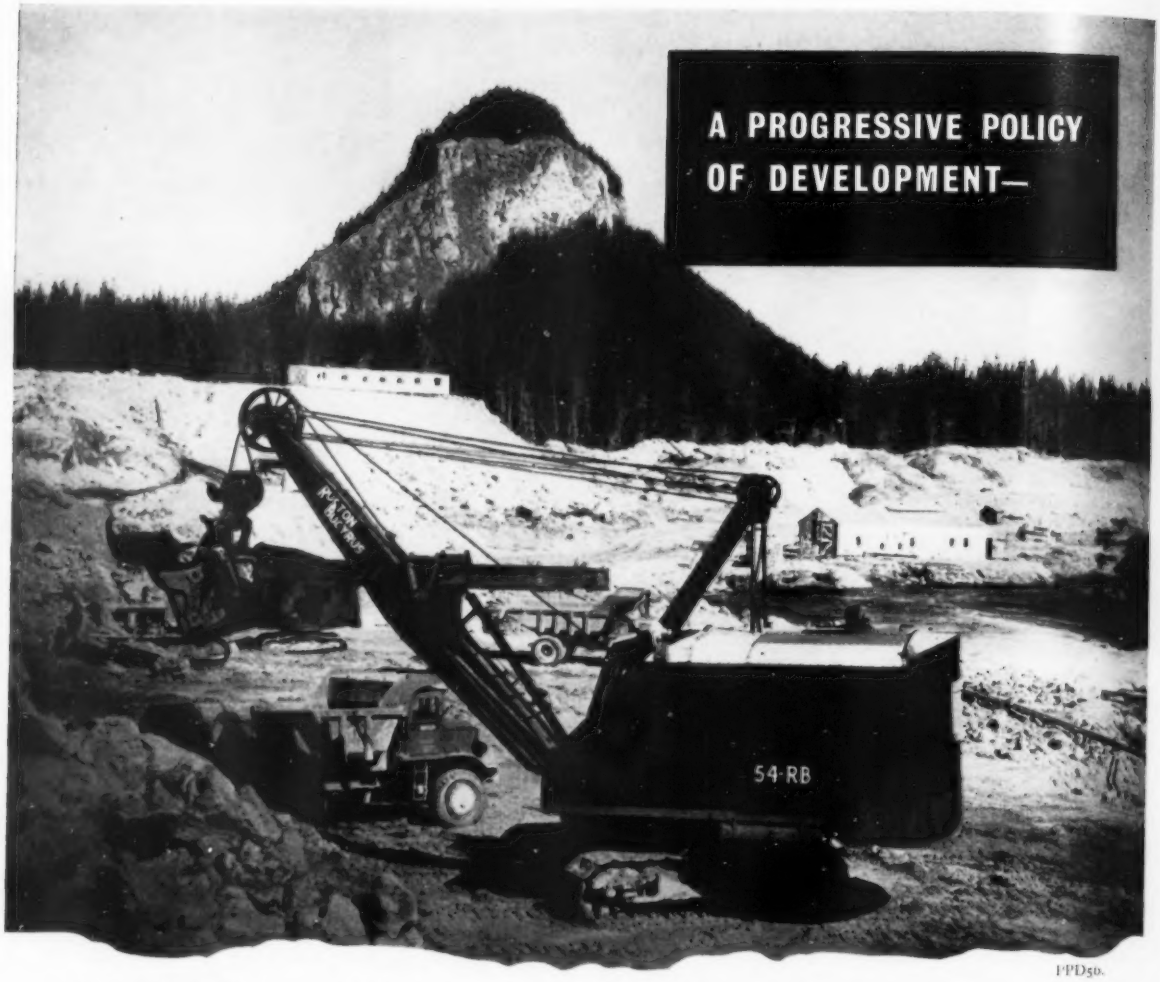

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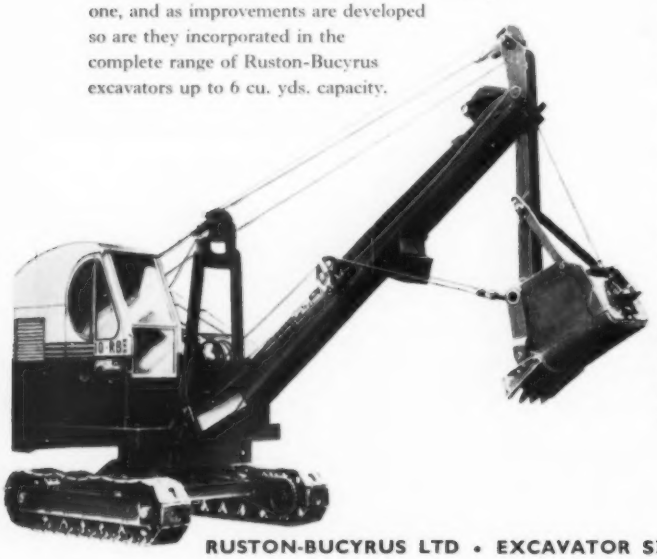
Improvements, represented by attention to detail, are continually being built into Ruston-Bucyrus excavators.

The process of development is a never-ending one, and as improvements are developed so are they incorporated in the complete range of Ruston-Bucyrus excavators up to 6 cu. yds. capacity.



R-B excavators in certain sizes are now being built with a re-designed cab in a new and attractive colour scheme, but neither design nor colour scheme has been introduced merely for the sake of change. Both in fact are the result of the policy of development in detail for the customer's benefit. But the excavator user is not just interested in visual improvements and likes also to know something of the heart of things. The heart of a diesel excavator is the engine and now all such R-B machines are fitted with diesel engines of improved design. Engine series YCN, YEN, and RPHN are representative of the latest in diesel prime mover development, a field with which the name of 'Ruston' has been constantly associated since the early days.

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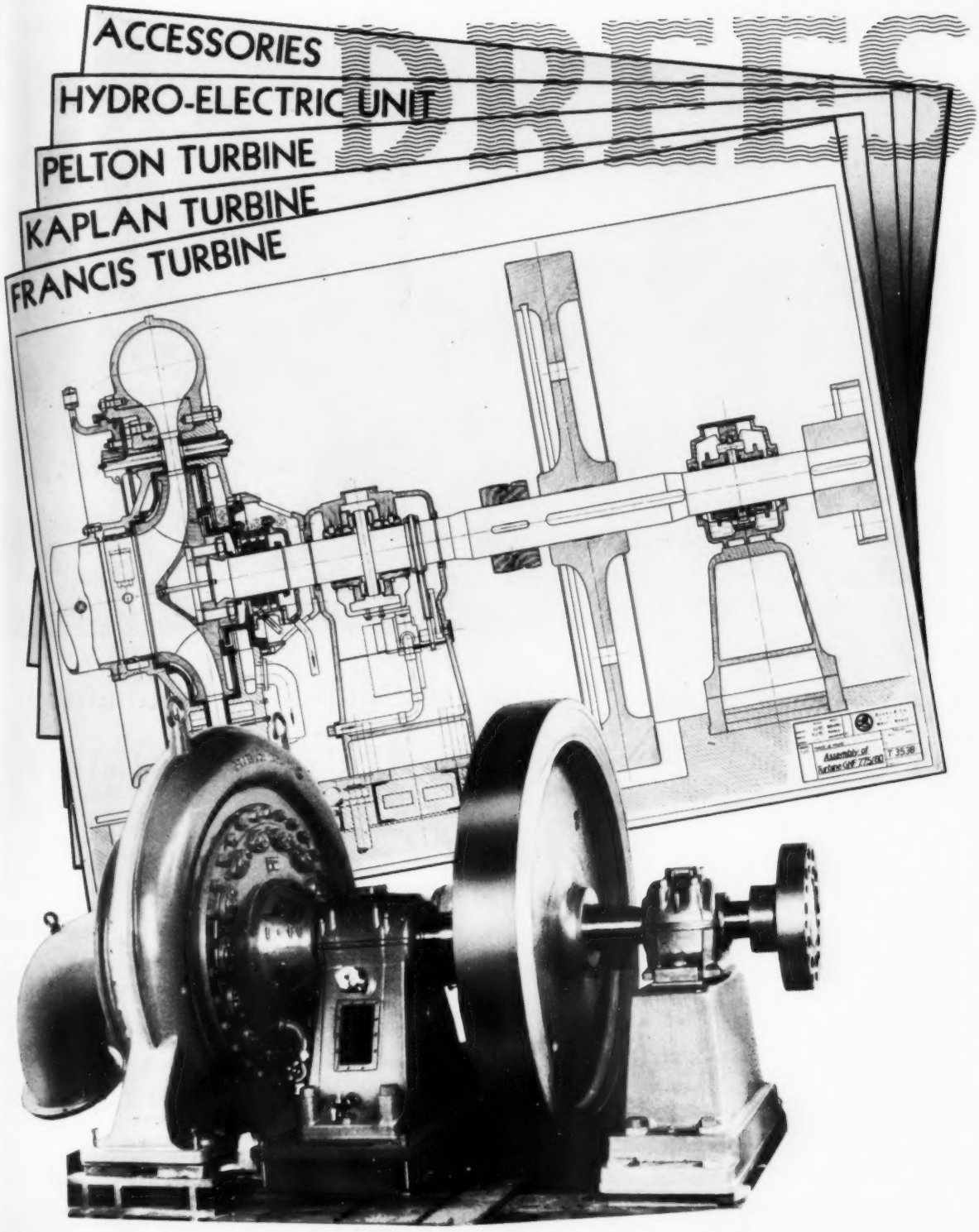

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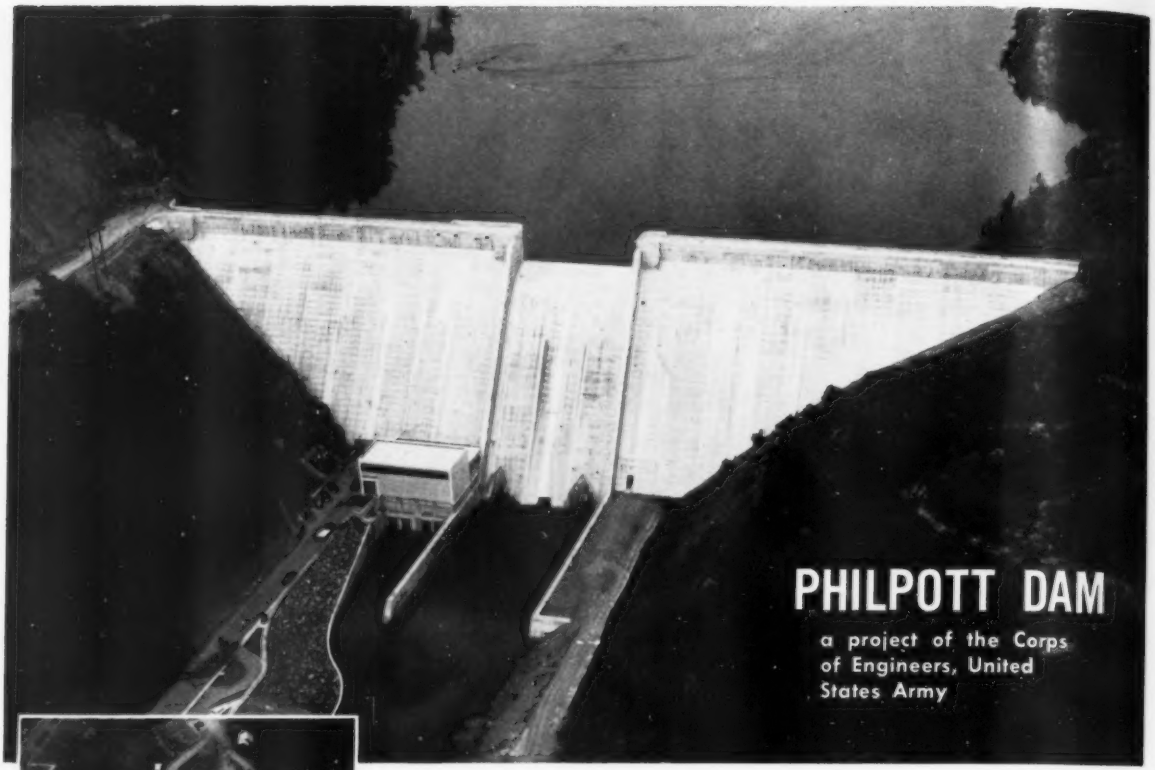
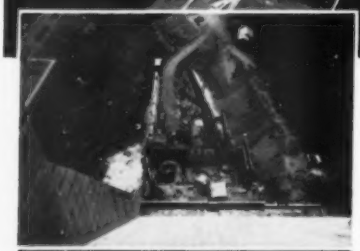
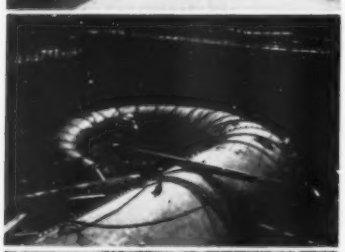
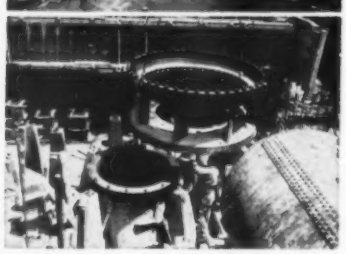


PHILPOTT DAM

a project of the Corps of Engineers, United States Army







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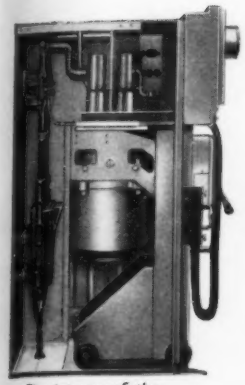

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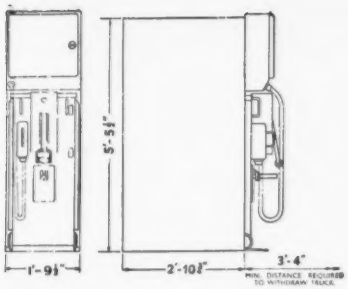

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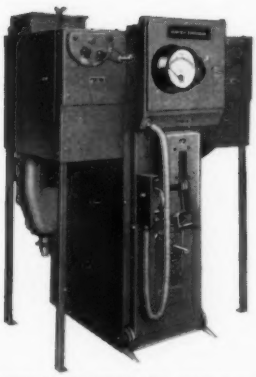

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Volume 8 Number 10

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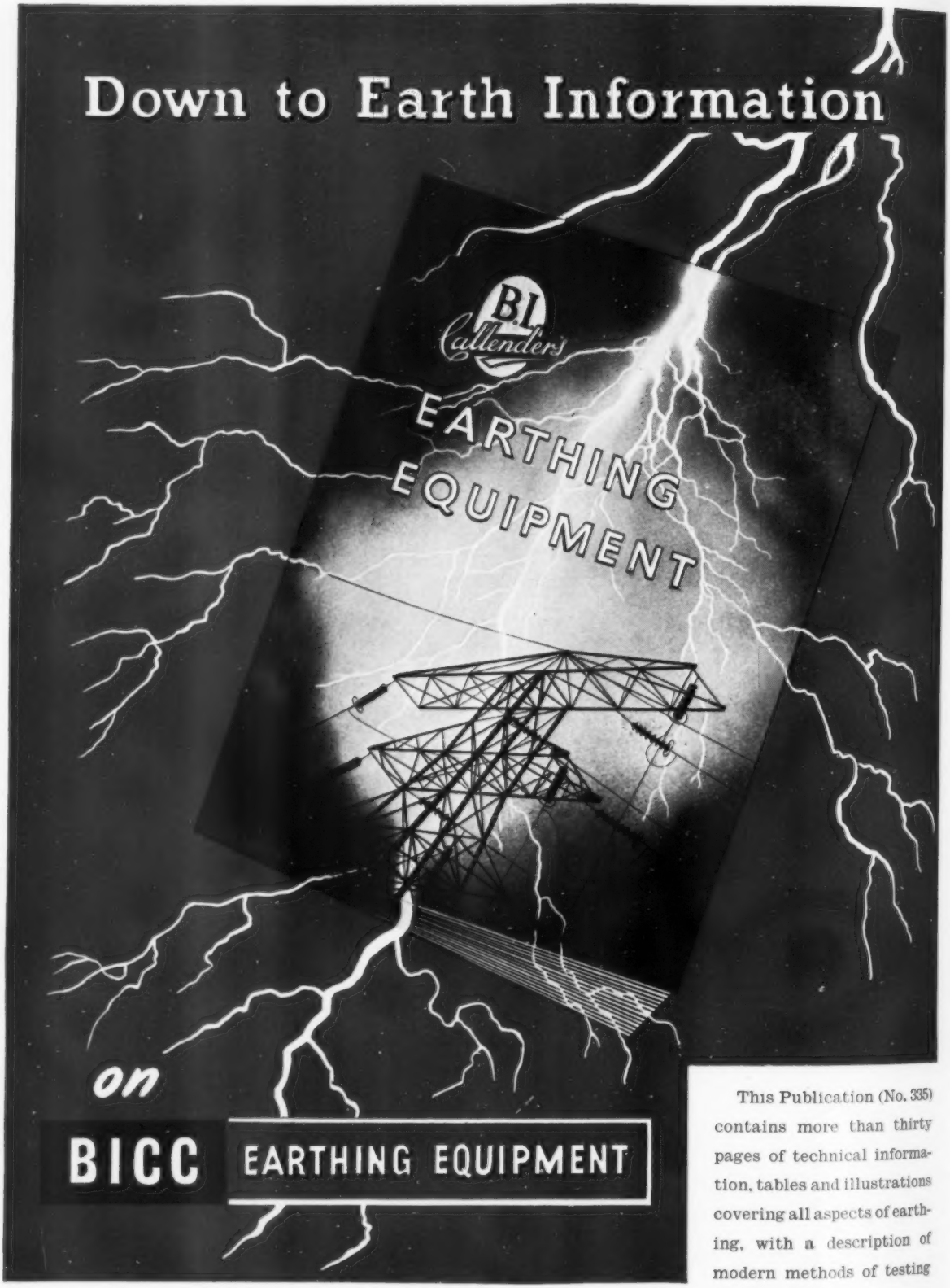

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WATER POWER

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Expanding Potentials

ONE of the most interesting trends in hydro-electric development during the last decade has been the discovery, in many very different parts of the world, that exploitable hydro-electric resources have greatly exceeded previous estimates. This process, moreover, appears to be a continuous one; each successive survey of any hydro-electric project seems to indicate that it can be made to produce more power than was at first thought possible.

There are many examples of long-established water-power plants which were designed originally to utilise the maximum energy that the stream was considered to deliver; but nevertheless these plants have been profitably re-equipped for much greater outputs. The main reasons why this has been possible may be summarised under several headings.

First, more comprehensive and reliable rainfall records are gradually becoming available, so that hydrographic data may be revised, usually in the direction of increased possibilities of power production. Further knowledge of underground conditions obtained through the utilisation of advanced geophysical exploration methods, enables run-off to be more accurately investigated, and in some cases to be controlled.

More economical tunnelling methods—developed notably in Sweden—have made it possible to bring water from adjacent unharnessed catchment areas into a reservoir, thus raising its water level and increasing its power potential.

The designers of water turbines are continually developing their three basic types of machine to enable each one of them to encompass a wider range of heads. This means that a given site can often be re-equipped to increase its power production and, in addition, the turbine manufacturers in recent years have developed the bulb-type machine with its several variants, so that lower and more variable heads on modest water courses can now be economically harnessed. The great reduction of capital cost which these units are theoretically capable of providing has meant already, and will mean to an increasing degree in the future, that small projects (the word small being used here in a relative sense, and including single units of up to 10 megawatts in capacity) can now be considered as economic, whereas previously the capital cost involved would have precluded their development.

There has also been a trend to group together power-generating organisations in one way or another. In some countries, this grouping has taken the form of over-all nationalisation, while in others the large-scale capital required for meeting the increasing demand for electricity has meant that small power companies have had to join up with their larger neighbours. In this way the number of separate power boards, power companies or other organisations has continued to decrease while the size of each unit has greatly increased. This has meant that a much greater degree of co-ordination in the planning of energy-production programmes has been possible. If separate authorities are considering the utilisation of the run-off from a particular mountain range, it is not likely that the total ouptut from their independent power producing plans will add up to the same figure as that which would result from a completely co-ordinated plan for the utilisation of the whole of the water power in the area concerned. This grouping into larger units for power production has therefore resulted in greater overall water-power potential.

Another parallel development which is also influencing the situation is the steady expansion of grid networks in every industrialised country of the world. In Great Britain, France, and the U.S.S.R., for example, where the whole of the electrical generating facilities are under State control, it is natural to find that transmission systems are either completely interconnected one with the other, or else plans are extant for such connections to be made. The Swedish 380 V line and the long direct-current lines being designed in Russia for interconnecting the whole of the vast Siberian water-power resources with those of the rest of the country are cases in point. In the United States,

prophecies were made at the recent World Power Conference that the whole country would be electrically interlinked within the next decade. Such an interconnection of thermal and hydro-power plants has invariably meant that both can be more efficiently operated. The thermal plants benefit by an improved load factor, thus raising their overall efficiency, while the hydro-plants in many cases are afforded much better scope in arranging for daily or seasonal regulation. This, in turn, tends to increase their annual contribution in kilowatt-hours to the total required from the supply system.

This interconnection has also benefited those countries where all the water courses are governed by similar hydrographical conditions. In these cases, such as in Spain, a prolonged drought might well mean and indeed, has meant, a power shut-down, with disastrous consequences to industry. In the past, the provision of costly storage facilities would have been the only method of ameliorating this position; but since the water courses may well provide excess power at certain times of the year, which could only be run to waste in the absence of load at that time, the presence of interconnecting systems enables such power to be exported, perhaps to ease the position on thermal power plants in another country; and thus the annual production figure from a station on one of these "flashy" rivers is enhanced. Pumped storage facilities, now being provided in increasing numbers, also tend to increase the overall hydro-electric production in a given area. This, of course, is particularly true when water power plants can be operated in conjunction with thermal plants.

The courageous experiment, on a major scale, now inaugurated in France in connection with the harnessing of tidal power by using totally submerged bulb-type units operating at low heads may well mean that rivers with shallow basins which have never been considered as suitable for harnessing from the hydro-electric point of view, may well be assessed from the power-production angle. It can thus be said that the hydro-electric engineer is doing his utmost to increase the contribution that his industry is making to the world's energy need; and, in spite of the inception of new methods of power production, there is every expectation that water power has an increasing part to play in the future—a part which is not only permanent but is increasing in magnitude, even in those areas of the world where great hydro-electric development has already taken place.

India's Hydro-Electric Resources Estimated at 35 million kW

THE Government of India's Central Water and Power Commission has released first reports of a survey of the country's hydro-electric resources. These are estimated at 35 million kW as contrasted with the 1921 estimate of 8 million kW at 100 per cent. load factor for the whole of undivided India. The survey is expected to be completed in 1958 when a more accurate estimate of the country's hydro-power potential will be available. In the meanwhile, in drawing conclusions it was neccesary to take into account the practical limitations of development, the feasibility of specific schemes and their financial soundness. In carrying out the present survey the country has been divided into six regions: (1) The west-flowing rivers of the Western Ghats; (2) the east-flowing rivers of South India; (3) the rivers of Central India; (4) the Gangetic basin; (5) the Brahmaputra basin; and (6) the Indus basin. The possibilitions of development in each basin were examined by a study of topographical maps and other data. The schemes have been drawn up in detail with indications of the locations of dam sites, their dimensions and reservoir capacities, the type and details of the water-channel systems and the location of power houses. Altogether 105 schemes producing 12·24 million kW have been incorporated in the reports on the surveys of the first three regions. The fourth report, on the Gangetic basin, is awaiting publication, and work on the other two regions is still in progress.

Most Powerful Kaplan Turbines

S. MORGAN SMITH Company of York, Pennsylvania, will build three 280 in. Smith Kaplan turbines for a U.S. Army, Corps of Engineers project. Installation will be at Ice Harbor Lock and Dam on the Snake River, 12 miles from Pasco, Washington. The turbines will operate over a head range of 78 to 102·5 ft. Their rating is 143,000 h.p. at 90 r.p.m. under an 89 ft. head. These are claimed to be the world's most powerful Kaplan turbines, surpassing even McNary which has a rated capacity of 111,300 h.p. under 80 ft. head. Shipment of embedded parts starts December 1, 1958, with completion of the third unit, July 1, 1960.

Heavy Power Equipment in Europe

THE O.E.E.C. annual survey of heavy equipment for power stations shows, in general, some improvement in European orders and deliveries as at January 1, 1956, and still better prospects for 1956. Deliveries of alternators for hydraulic turbines (10 MW and over) made during 1955 were greater than during any other postwar year, although, as recorded for the period 1952-54, the yearly increases were only very small. In 1955, arrears in shipments occurred, as during the period April-December 1955 only 3,371 MW left manufacturers' plant compared to programmes for dispatch between April 1, 1955, and March 31, 1956, totalling 4,783. Member countries, both producer countries and others, were affected by these delays in dispatch of equipment, whereas deliveries to non-member countries and overseas territories were made according to schedules recorded by the 8th survey (April 1, 1955). For the first time since 1951 the total of orders in hand for delivery in the subsequent four years considerably increased between April 1, 1955 (8th survey) and January 1, 1956 (9th survey). The rise amounted to 1,988 MW, thus bringing the volume of order books to 13,289 MW.

In spite of the increase of 254 MW over 1953 shipments of hydraulic turbines (10 MW and over), which brought the total for 1955 to 4,535 MW, deliveries in 1955 remained substantially below their highest postwar level of over 5,000 MW, attained in 1952. Those to non-member countries and overseas territories and those to other member countries were, however, greater than ever since 1948. Deliveries in producer countries oscillated around 2,000 MW during the

period 1953-55. As a whole, manufacturers appear to have lived up to delivery programmes of the last survey as regards shipments of hydro-power plants located in member countries. The dispatch of turbines to non-member countries and overseas territories, however, fell in arrears. In 1956 total shipments should be increased and, due to a substantial rise scheduled for deliveries to member countries, attain the record level of 1952. The dispatch of turbines to non-member countries and overseas territories will decrease; it appeared noteworthy, however, that orders from this area booked as at January 1 already call for substantially higher deliveries than ever before in 1957. Between April 1, 1955, and January 1, 1956, when 3,663 MW were dispatched, order books comprising shipments during the next four years increased by 1,940 MW to 13,613 MW.

Orders for power transformers (5 MVA and over) placed as at January 1, 1956, for delivery in 1956 were, both in the case of member countries combined and of non-member countries and overseas territories, only slightly smaller than actual shipments in 1955. Taking into account the relatively short delivery periods for these transformers, it appears certain that 1956 deliveries will again exceed those recorded for 1955.

Bulgarian Dam Completed

THE largest dam in Bulgaria—the Stalin dam on the river Isker—has been completed. Construction was commenced in 1951, and the dam comprises 220,000 cu. m. of concrete faced with 8,000 cu. m. of red sandstone which harmonises with the neighbourhood. The storage capacity provided is 670,000 million cu. m. The Stalin dam is the starting point of a power and irrigation scheme covering 155,000 acres of the Sofia plain. The Passarel and Kokalyane power stations, using waters from this dam, are to be brought into commission this year, and are expected to generate over 170 million kWh per annum. This will be an important contribution towards a planned increase in electricity output this year of 345 million kWh. This will bring the gross annual output per head of population to 310 kWh as against 44·6 in 1944.

Norwegian-Russian Power Project

NORWEGIAN and Russian experts have been meeting recently to discuss the practical details of a scheme for joint exploitation of the hydro-electric potential in the Pasvik river which forms part of the frontier between Norway and the Soviet Union in the Far North. According to Norwegian Minister of Industry, Gustav Sjaastad, preliminary agreement has been reached for building power stations at two places, Skoltefoss and Skogfoss. The stations could have a capacity of about 30 MW each.

Indian Second Five-Year Plan

THE Indian Government has recently published its second Five-Year Plan, the first plan, for a similar period, having been completed in March 1956. The foreword emphasises that none of the figures or proposals should be regarded as inviolable, since it is intended that the plan should be worked in a flexible manner. In the power-generation field the projects in the second plan are estimated to produce an additional 3·5 million kW, this bringing the total installed capacity from 3·4 million kW to 6·9 million kW. Of the total capital outlay of Rs. 427 crores in the public sector for power, Rs. 235 crores will be spent on generation, Rs. 92 crores on transmission, Rs. 25 crores on distribution in rural areas and Rs. 75 crores on small town and rural electrification. The estimated consumption of electricity in 1960 (excluding energy consumed by industrial establishments with their own generating plants) will be 16,600 million kWh, of which 12,000 million will go to industrial uses and 1,480 million to domestic use. The main new schemes to be started in the second plan are given in the following table, which shows, however, the total power that will be available when the individual schemes are completed: it should be realised that only a proportion of this power will be available during the period of the second Five-Year Plan.

	Megawatts
Ukai (Bombay)	160
Chambal—Stage 2	92
Sileru (Andhra)	75
Tungabhadra, Nellore (Andhra and Mysore)	66
Korba (Madhya Pradesh)	90
Southern Grid Extension (Madhya Pradesh)	60
Kundah (Madras)	180
Hirakud—Stage 2 (Orissa)	109
Yamuna Hydel (Uttar Pradesh)	201
A scheme in Western Uttar Pradesh	75
Durgapur (Thermal Plant)	150
Bokaro Extension	50
Pamba or Poringalkuthu (Travancore Coshin)	75
Calcutta Electricity Supply	50
Ahmedabad	45
Trombay	100
Bhira Extension	60

Remote-Control Power Plant for Australia

A POWER plant which will be operated by remote control through a radio link from a station 12 miles away is to be equipped by The English Electric Co. Ltd. for the Electricity Commission of New South Wales. The new station is to be built on the Warragamba River, at a point about 12 miles from Penrith, as part of the Warragamba hydro-electric project. The main purpose of the dam is to store water for supply to Sydney and the surplus water is to be used for generating power. The plant will be additional to the main power network in New South Wales and will be operated in conjunction with the network's steam stations either as a peak-load station or for continuous running as the Electricity Commission decides.

The comprehensive contract awarded to English Electric covers the installation of a 69,000 h.p. reaction turbine, directly coupled to a 62·5 MVA alternator, and this generating unit will be connected into the electricity supply through a 62·5 MVA step-up transformer for transmission at 132 kV. Other equipment to be supplied includes a 250 kVA auxiliary transformer, the station crane, and all associated power cables, switchgear, control and communication equipment.

Fig. 1. Dam site at Ajena, looking upstream

The Volta River Project

We publish a brief commentary on the Volta project in the light of the Report just published by H.M. Government

ON July 27 last there was published in London a substantial Report* in three volumes on the Volta River project. Reference has been made to the project, from time to time, in the pages of WATER POWER, and since it is hoped that more will be heard of this scheme, it may be advantageous to recapitulate the background as far as it is known to us.

The Gold Coast occupies a position of peculiar interest as it seems likely it will very shortly become the first all-African Commonwealth Government. At present the economy of the country is largely linked to cocoa, an extremely valuable crop. However, the Gold Coast also possesses very large deposits of high-grade bauxite estimated to amount to over 200,000,000 tons, and one large river, the Volta, which is capable of producing economically at least three-quarters of a million kilowatts of continuous electrical power. The association of these two resources in the same country makes for an ideal situation for producing aluminium, and the purpose of the Volta scheme is just that, with additional power to supply other new industries which may grow up following the diversification of the Gold Coast economy.

The original conception of an integrated scheme may be credited to Mr. A. E. Kitson (later Sir Albert Kitson, C.M.G., C.B.E.), a former director of Geological Surveys in the Gold Coast, who propounded his scheme over 40 years ago in 1915. However, the first definite scheme was produced by an energetic and far-sighted South African civil engineer, Mr. Duncan Rose, who formed a company to exploit the possibilities, and evolved a scheme with his Consulting Engineer, Mr. C. St. John Bird.

In 1949, the Gold Coast Government realised that matters had progressed a long way and engaged Sir William Halcrow and Partners, Consulting Engineers, of London, to advise them on the scheme and, indeed, on the whole development of the Volta basin. Their terms of reference enabled the Consulting Engineers to treat the development of the basin on a national scale instead of on the more limited scale of a simple commercial venture, and their report was published in 1951. In general they confirmed the findings of West African Aluminium Limited that the Volta scheme was technically feasible and economic, and went on to show how the aluminium project would form only a part of a widespread development of the Volta basin. In addition to the establishment of a power development and aluminium industry, they recommended the

* Report of Preparatory Commission, £1 15s.; Appendices, £5 10s.; Engineering Report, £8 15s. Published by H.M. Stationery Office.

construction of a system of railways and roads interconnecting the main parts of the project among themselves and with existing towns. The creation of an entirely new major port to serve the country was also recommended, together with a new bridge over the Volta River to provide a trunk road from the Gold Coast to Togoland. Irrigation of more than half a million acres of the presently dry Accra plains was also recommended.

At about the same time that the Consulting Engineers reported to the Government, Aluminium Limited, of Canada, and the British Aluminium Company became interested in the venture and made their own study of the project. In 1952, Her Majesty's Government issued a White Paper† on the Volta River Aluminium Scheme in which it was said that in principle Her Majesty's Government in the United Kingdom favoured participation in the scheme which would further their policy of developing the resources of the Commonwealth as well as contributing to the raw-material needs of the United Kingdom. They believed that the scheme was soundly conceived, but its magnitude was such that it should not be embarked upon without every practical assurance that it could be carried through to a successful conclusion. They accepted the Consulting Engineers' suggestion that a Preparatory Commission should be set up, and on February 17, 1953, a Special Commissioner was appointed in the Gold Coast.

The reaction of the Gold Coast Government was somewhat more positive. The country realised clearly that it was presented with a stimulating solution to some of its difficulties, and in the five years since publication of the original report it has courageously set in motion the construction of a new £10,000,000 harbour at Tema, and has completed or has under construction some 45 miles of trunk roads and about 35 miles of railway lines connecting Tema to existing communications. Perhaps the most spectacular achievement to date has been the closure on July 24

† "The Volta River Scheme," WATER POWER, January 1953, p. 26.

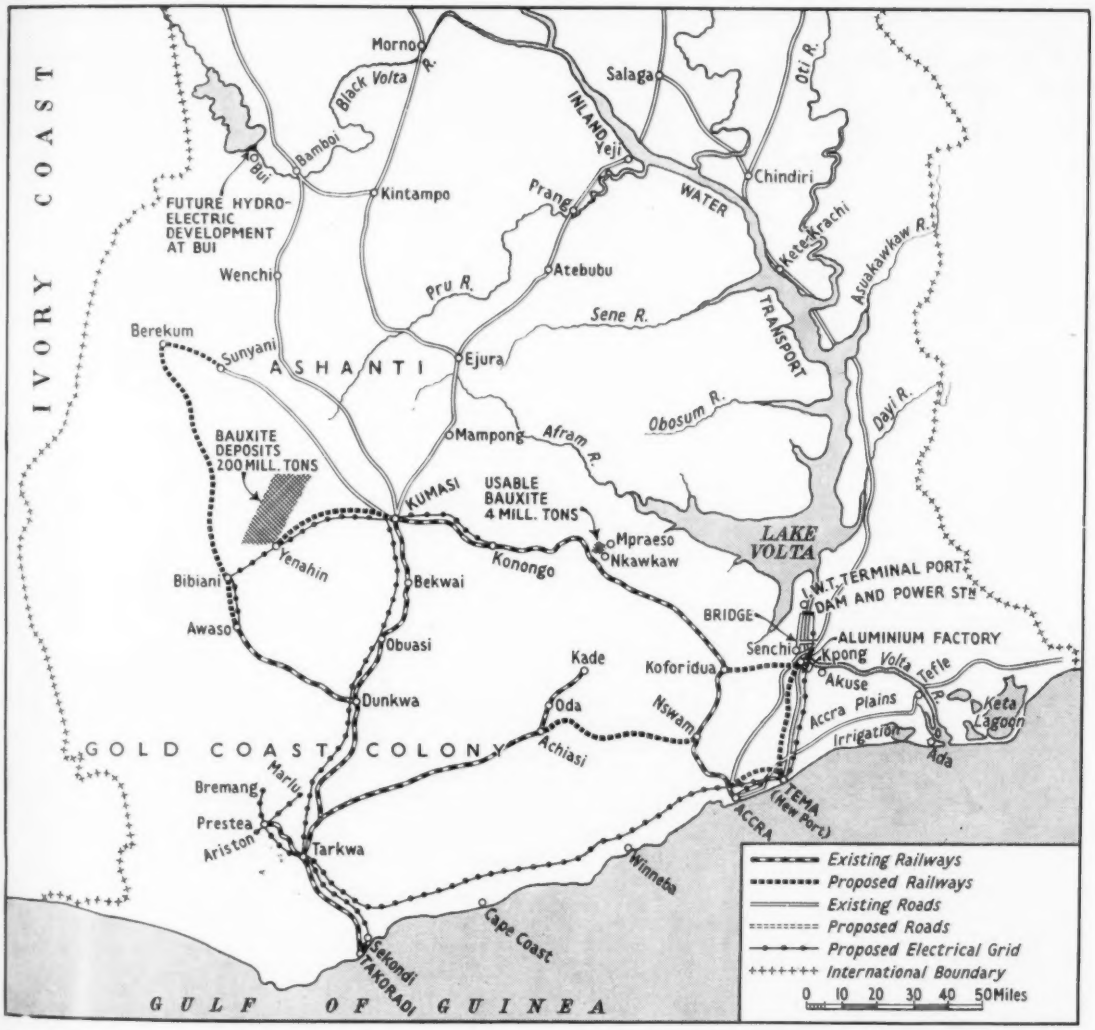


Fig. 2. Map showing site of dam and reservoir in rela tion to bauxite deposits, aluminium works and the new port of Tema

Fig. 3. Dam site at Bui looking downstream

of a great steel arch bridge of 805 ft. clear span across the Volta River some distance below the future dam site.

Behind the new Port of Tema, the Tema Development Corporation has under construction a new town, planned to accommodate up to 50,000 people. All these works are being financed by the Gold Coast Government which has wisely applied part of its cocoa revenue for development schemes. Indeed the acceptance by the cocoa-growing community of such a large levy is probably quite exceptional in African affairs.

While all this work has been going on, it is clear from the Report now under consideration that the Consulting Engineers' staff have also been busy developing the details of the power scheme to an exceptional degree. This was made possible by the work of the Preparatory Commission under its active Chairman, Sir Robert Jackson. The Commission has quite clearly set out to explore every implication of the scheme from the financial and social aspects as well as from the technical aspects.

The three volumes of the present Report represent a remarkable degree of investigation, and the Commission concludes that, subject to certain reservations, the Volta River Project is (1) technically sound, (2) could be constructed successfully, (3) could be operated competitively, (4) could not be significantly improved from an economic point of view, (5) would bring its greatest return if maximum production were to be achieved as soon as possible, and (6) would not endanger health.

At the time the 1951 Volta Report was published there was very considerable disillusionment over "ground nuts" and Abadan, and since the sums of money involved numbered many millions of pounds to be invested in a country so little-developed as the Gold Coast, the Preparatory Commission studied every aspect of the project and its probable impact on the country's economy. Experts from various parts of the world have reported on economic, sociological and human and health problems, while the engineering surveys and investigations have been carried to a degree that seems quite exceptional. There is, therefore, a clear assessment of the costs and risks which should enable the participants, the two Governments and the Aluminium Companies, to decide whether to commit themselves further.

The estimated inclusive costs—£160,000,000 for the initial stage and £230,000,000 for the final stage now proposed by the Preparatory Commission—are considerably higher than those originally embodied in the White Paper, and it is clear that apart from inflation and the building of a bigger scheme, the extent and scale of the contingencies and obligations to be charged against the project have been considerably increased.

Fig. 4. Meteorological station at Accra

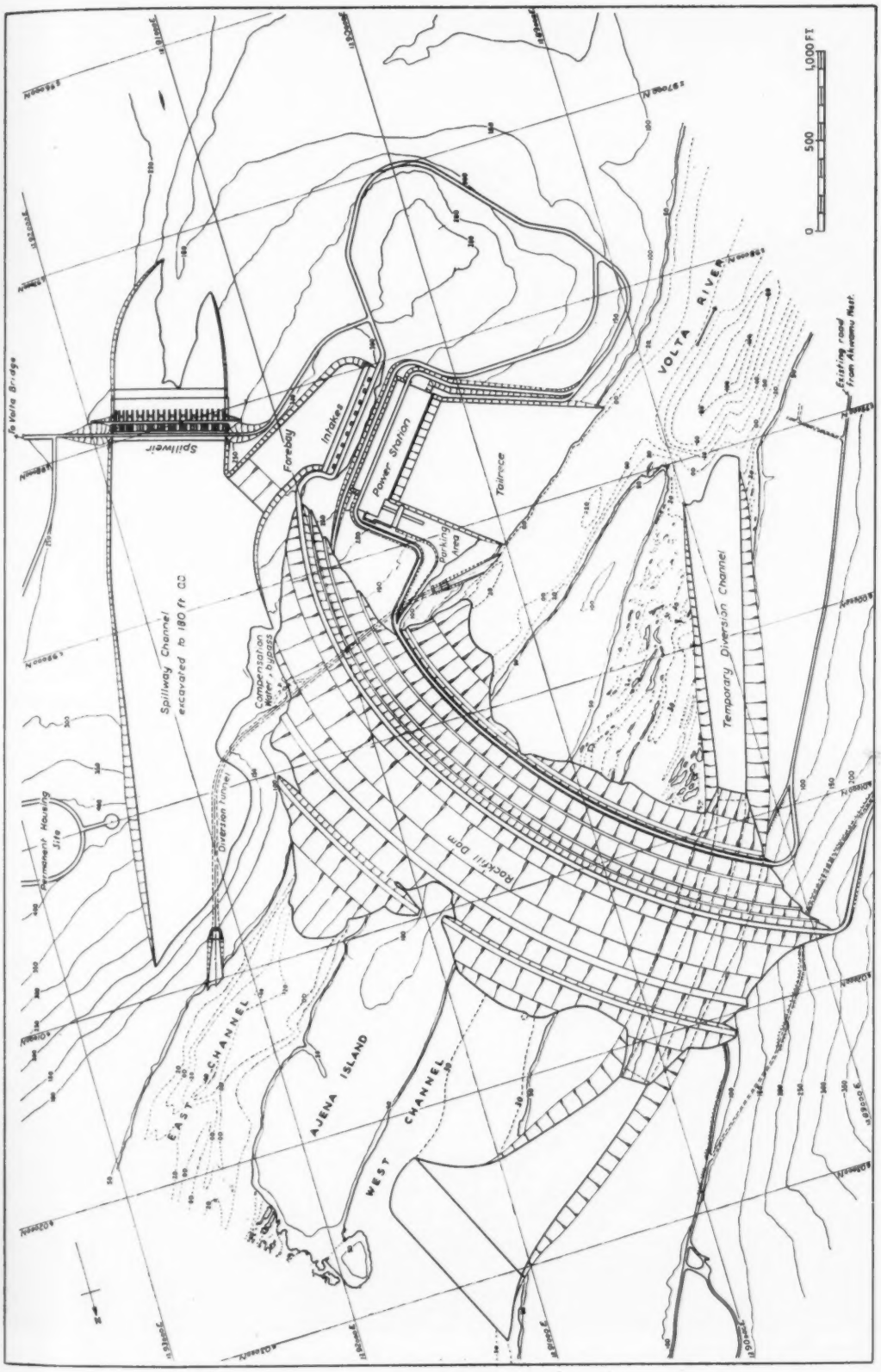


Fig. 5. General plan of dam and powerhouse

Fig. 6. Ajena Bridge spanning Volta River

Discussions between the two Governments and the Aluminium Companies were reported to have taken place earlier this year and doubtless the validity and allocation of charges requires discussion. However, this is a problem facing all joint ventures, and the fact that the Report has been published at all lends hope for optimism.

Volume III, the engineering part of the Report, gives many details of the scheme. It is proposed to build a very large rockfill dam at Ajena, some 70 miles inland from Tema and Accra. This dam would be of the order of 300 ft. high and would raise the dry-season water level at the site by about 230 ft. Because the gradient of the Volta is so flat upstream there would be created an enormous lake some 250 miles long with an area of nearly 3,500 sq. miles. The total catchment area is some 152,000 sq. miles and about 19 years of river gaugings are available, together with rainfall records over a more extended period. The Consulting Engineers appear to disagree with the other experts consulted by the Preparatory Commission on the value of the evaporation from the lake and they estimate the long average regulated discharge at about 38,000 cusecs. The scheme is ranked industrially as equivalent to 633 MW of firm continuous power, but provision may have to be made in the future for abstraction of water for irrigation which would reduce the firm power available to industry to perhaps 617

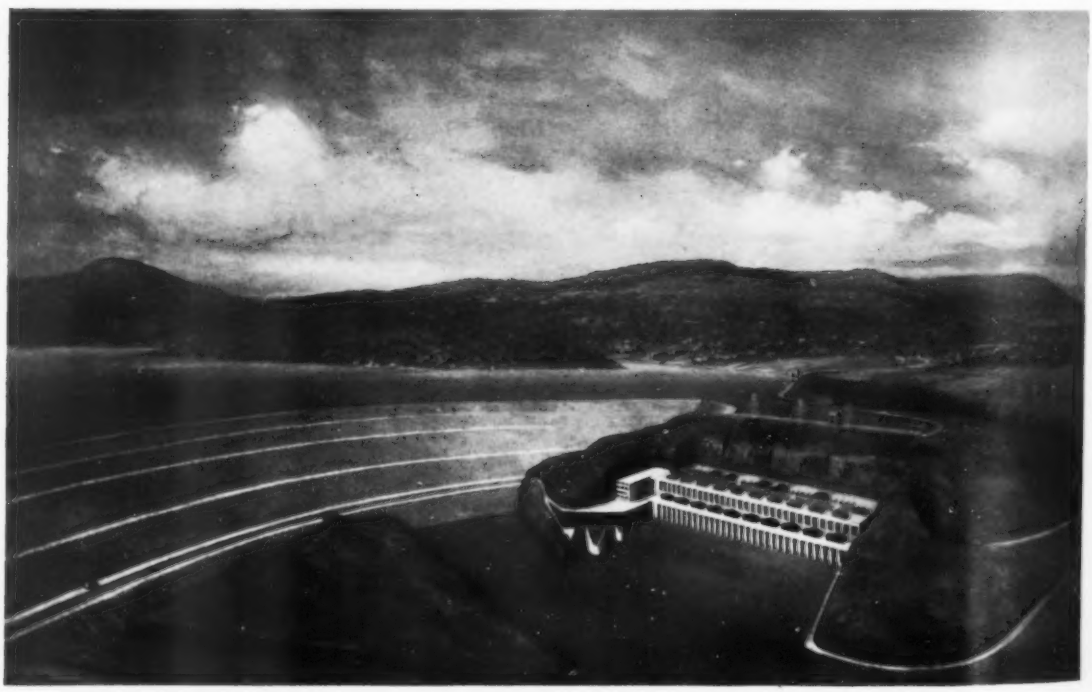


Fig. 7. Volta River; impression of finished dam and powerhouse based on model

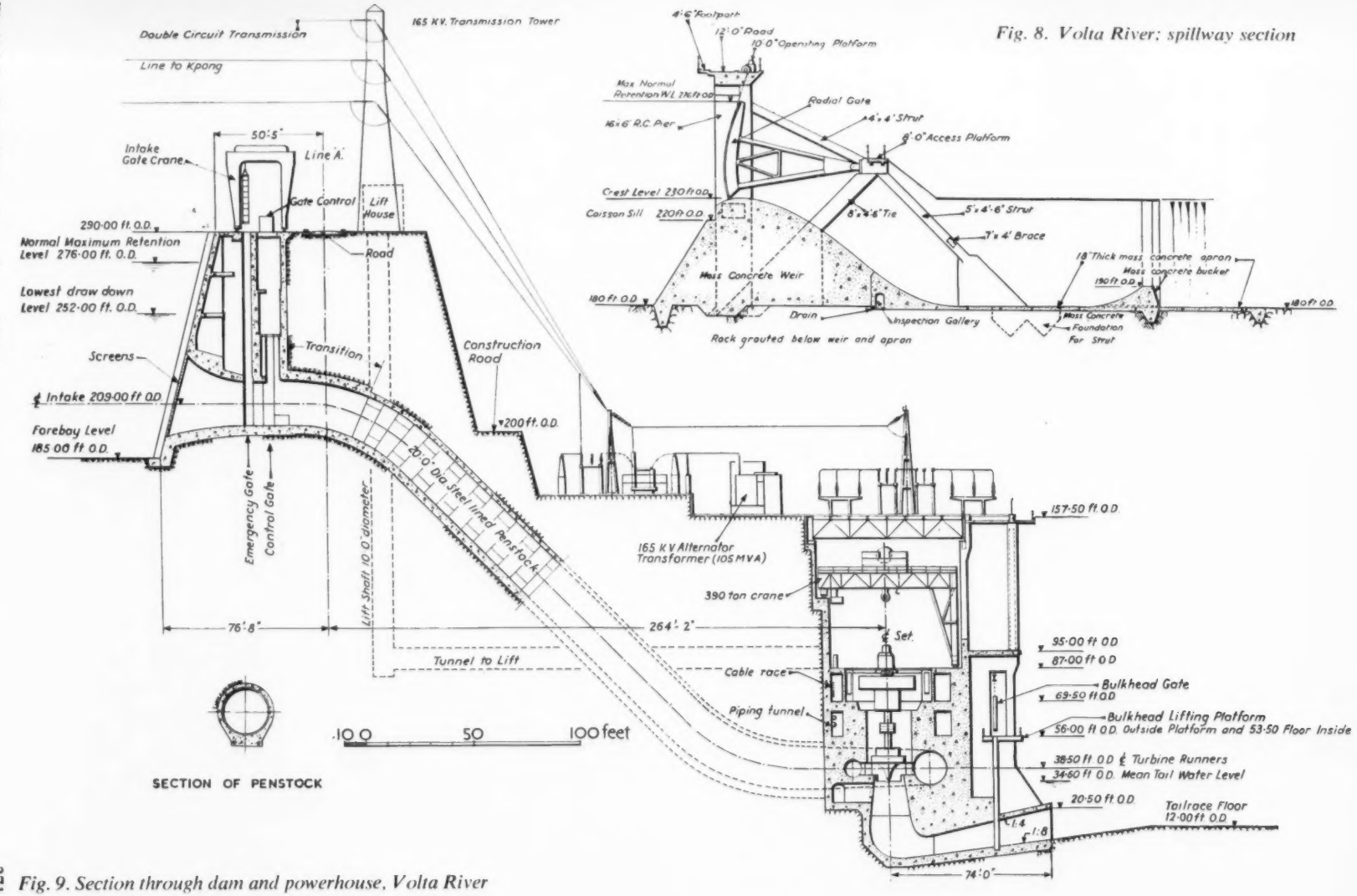


Fig. 8. Volta River: spillway section

Fig. 9. Section through dam and powerhouse, Volta River

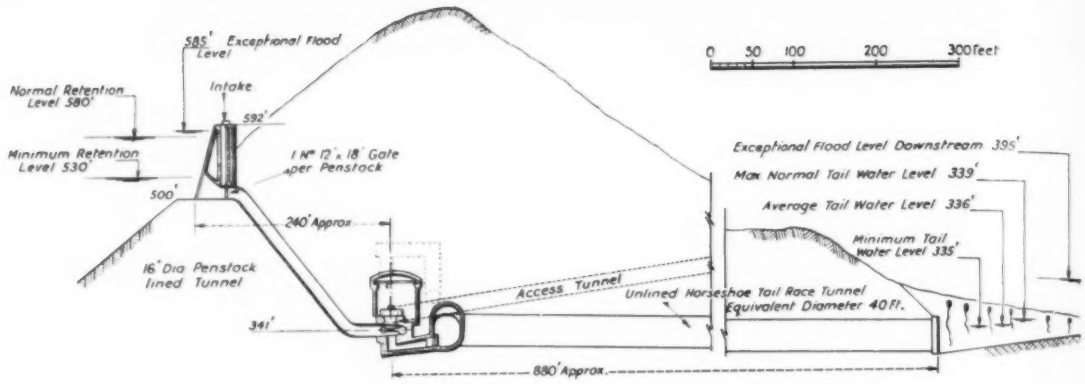


Fig. 10. Section through dam and power station, lower Bui Gorge site

MW continuous. Provision is made in the power station for nine sets of 90 MW capacity each, which should permit of competitive tendering as sets of this size could be built by a number of manufacturers. The power station is conventional except that part of the switchgear will sit on the roof, and considerable attention is to be paid to its appearance and natural setting.

It is now proposed that the smelter should be at Kpong, about 17 miles downstream, and that the power should be transmitted to it at 165 kV, losing approximately 9 MW on the way. The generator voltage would be 15 kV and the electrical layout devised by the Consultants' advisers, Messrs. Ewbank & Partners, is given in some detail in the Report. At the smelter the current would be rectified and supplied to the pot lines at low voltage direct current. At the Kpong substation provision is also made for power supply to other parts of the Gold Coast.

Apart from surveys and designs the investigational work already carried out on site has been considerable. A great deal of work has been done on evaporation. Many thousands of feet of rock borings have been put down. A substantial quarry at the site of the dam has been opened up with test blasting, and a 30 ft. high experimental clay embankment to simu-

(Continued on page 376)

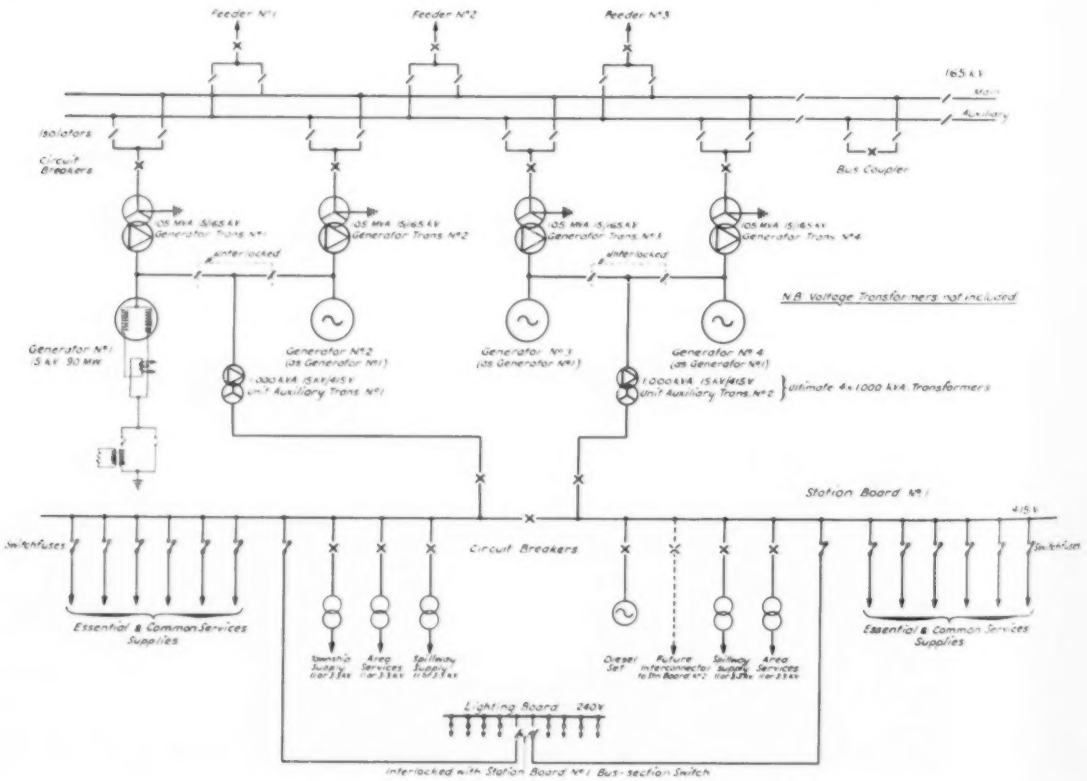
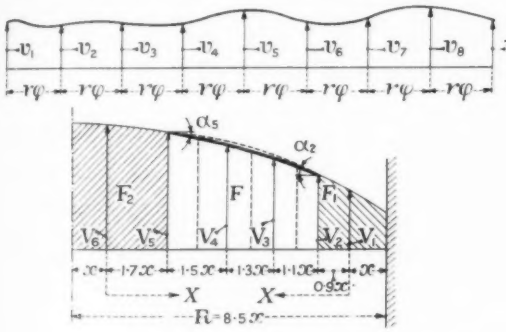


Fig. 11. Electrical circuit diagram, Volta River scheme

Calculating Flow through Penstocks

Sigfrid Andersson applies the method of calculation explained in his previous article on flow through turbines* to the evaluation of flow through a circular penstock

WHEN measuring the flow in a circular penstock by means of current meters, the meters can be placed on a rod that is capable of rotating around an axis at the centre of the penstock. The current-meter rod can then be stopped at different positions around the axis and thus a number of measuring points obtained. If the rod is turned at a constant and not too great a velocity, so-called integration measurement can be made; i.e., each current meter will indicate an average vector V, after the current-meter rod has made one complete revolution. Here the assumption has been made that for $m = 6$ current meters and $p = 8$ positions; the resultant division is made according to the following:—



$$F_{chord} = r\phi \left(\frac{v_1 + v_2}{2} + \frac{v_2 + v_3}{2} + \frac{v_3 + v_4}{2} + \frac{v_4 + v_5}{2} + \frac{v_5 + v_6}{2} + \frac{v_6 + v_7}{2} + \frac{v_7 + v_8}{2} + \frac{v_8 + v_1}{2} \right)$$

$$F_{chord} = r\phi\,(v_1 + v_2 + v_3 + v_4 + v_5 + v_6 + v_7 + v_8) \qquad \ldots(1)$$

$$F_{tangent} = r\phi\,(v_1 + v_2 + v_3 + v_4 + v_5 + v_6 + v_7 + v_8) \qquad \ldots(2)$$

F_{chord} being in this case $= F_{tangent}$, it is not possible to estimate the area by means of $F_{chord} + \frac{2}{3}(F_{tangent} - F_{chord})$ as done in the previous article, because the correction does not exist. The average velocity vector v for a circumference will thus be:

$$V = \frac{1}{8}(v_1 + v_2 + v_3 + v_4 + v_5 + v_6 + v_7 + v_8) \qquad \ldots(3)$$

If the Simpson formula is used,

$$F_{Simpson} = \frac{r\phi}{3}(v_1 + 4v_2 + 2v_3 + 4v_4 + 2v_5 + 4v_6 + 2v_7 + 4v_8 + v_1)$$ is obtained, and

$$V = \frac{1}{12}(v_1 + 2v_2 + v_3 + 2v_4 + v_5 + 2v_6 + v_7 + 2v_8)$$

Which of these two formulae it is most advisable to use can probably only be determined statistically if in fact there is any difference at all between them. In the author's opinion the investigation in the previous article leads to the assumption that from the accuracy standpoint it is comparatively unimportant which formula is chosen. Nevertheless, the first mentioned formula is preferable, as it uses only unit factors in the calculation table. The average velocity vectors V then form a curve, which consequently lies along a radius. The water volume can then be estimated by applying the Guldin rule to the surface below this curve. The distance from the outer current meter to the wall should be about 125 mm. for all diameters above 1,500 mm. In the case of smaller penstock diameters it would probably be better to use current meters of smaller diameters than those of the Ott type generally used, which are 100-125 mm. in diameter, so as to allow them to be placed nearer to the wall. Each current meter should if possible represent about the same proportion of the measuring area, but this meets with certain difficulties at the periphery, where it is not possible to go too near to the wall.

The areas F_1, F_2 and F are estimated as follows:

A parabola $V = a + bX + cX^2$ is drawn through V_1, V_2 and V_3, when α_2 and F_1 can be calculated.

For $X = 0$ $V_1 = a$ is obtained ...(4)

„ $X = 0{\cdot}9x$ $V_2 = a + b0{\cdot}9x + c0{\cdot}81x^2$ „ „ ...(5)

„ $X = 2{\cdot}0x$ $V_3 = a + b2x + c4x^2$ „ „ ...(6)

From this equation system b and c are solved.

$$b = \frac{-3{\cdot}19V_1 + 4V_2 - 0{\cdot}81V_3}{1{\cdot}98x} \qquad \ldots(7)$$

$$c = \frac{1{\cdot}1V_1 - 2V_2 + 0{\cdot}9V_3}{1{\cdot}98x^2} \qquad \ldots(8)$$

$$\frac{dV}{dX} = b + 2cX$$

For $X = 0{\cdot}9x$ is obtained

$$\frac{dV}{dX} = b + 1{\cdot}8cx = \tan x_2$$

$$\tan \alpha_2 = \frac{-3{\cdot}19V_1 + 4V_2 - 0{\cdot}81V_3}{1{\cdot}98x} + 1{\cdot}8\,\frac{1{\cdot}1V_1 - 2V_2 + 0{\cdot}9V_3}{1{\cdot}98x}$$

$$\tan \alpha_2 = \frac{1}{1{\cdot}98x}(-1{\cdot}21V_1 + 0{\cdot}4V_2 + 0{\cdot}81V_3) \qquad \ldots(9)$$

A parabola $V = a + bX + cX^2$ is drawn through V_6, V_5 and V_4 whereupon α_5 and F_2 can be calculated.

For $X = 0$ $V_6 = a$ is obtained ...(10)

* "Calculating Flow Through Turbines." By Sigfrid Andersson. WATER POWER, June 1956 p. 216, July 1956 p. 269.

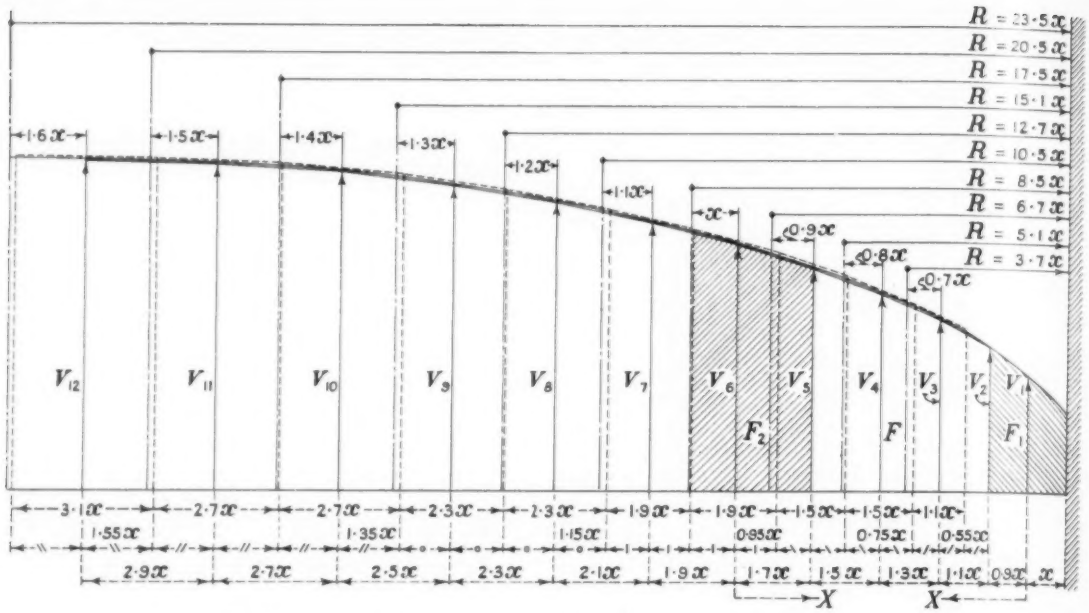


Fig. 1. Pattern of current-meter positions at different tube diameters

A suitable value of x would be $120 < x < 165$ mm.

For $X = 1{\cdot}7x$ $V_5 = a + b1{\cdot}7x + c2{\cdot}89x^2$ is obtained ...(11)

„ $X = 3{\cdot}2x$ $V_4 = a + b3{\cdot}2x + c10{\cdot}24x^2$ „ ...(12)

From this equation system b and c are solved.

$$b = \frac{-2{\cdot}89V_4 + 10{\cdot}24V_5 - 7{\cdot}35V_6}{8{\cdot}16x} \quad ...(13)$$

$$c = \frac{1{\cdot}7V_4 - 3{\cdot}2V_5 + 1{\cdot}5V_6}{8{\cdot}16x^2} \quad ...(14)$$

$$\frac{dV}{dX} = b + 2cX$$

For $X = 1{\cdot}7x$ is obtained

$$\frac{dV}{dX} = b + 3{\cdot}4cx = \tan\alpha_2$$

$$\tan\alpha_5 = \frac{-2{\cdot}89V_4 + 10{\cdot}24V_5 - 7{\cdot}35V_6}{8{\cdot}16x} + 3{\cdot}4\,\frac{1{\cdot}7V_4 - 3{\cdot}2V_5 + 1{\cdot}5V_6}{8{\cdot}16x}$$

$$\tan\alpha_5 = \frac{1}{8{\cdot}16x}(2{\cdot}89V_4 - 0{\cdot}64V_5 - 2{\cdot}25V_6) \quad ...(15)$$

The area F_1 can now be calculated by integration

$$F_1 = \int_{-x}^{0{\cdot}9x}(a + bX + cX^2)\,dX = \left[aX + \frac{b}{2}X^2 + \frac{c}{3}X^3\right]_{-x}^{0{\cdot}9x}$$

$$F_1 = a(0{\cdot}9x + x) + \frac{b}{2}(0{\cdot}81x^2 - x^2) + \frac{c}{3}(0{\cdot}729x^3 + x^3)$$

$$F_1 = x(2{\cdot}37324V_1 - 0{\cdot}77407V_2 + 0{\cdot}30083V_3) \quad ...(16)$$

In the same way the area F_2 is calculated,

$$F_2 = \int_{-x}^{1{\cdot}7x}(a + bX + cX^2)\,dX = \left[aX + \frac{b}{2}X^2 + \frac{c}{3}X^3\right]_{-x}^{1{\cdot}7x}$$

$$F_2 = a(1{\cdot}7x + x) + \frac{b}{2}(1{\cdot}7^2x^2 - x^2) + \frac{c}{3}(1{\cdot}7^3x^3 + x^3)$$

$$F_2 = x(0{\cdot}07594V_4 + 0{\cdot}41294V_5 + 2{\cdot}21112V_6) \quad ...(17)$$

F is calculated as a chord trapezium which is adjusted by two thirds of the difference between the tangent and chord trapezium.

$$F_{chord} = x\left(\frac{V_2 + V_3}{2}1{\cdot}1 + \frac{V_3 + V_4}{2}1{\cdot}3 + \frac{V_4 + V_5}{2}1{\cdot}5\right)$$

$$F_{chord} = x(0{\cdot}55V_2 + 1{\cdot}20V_3 + 1{\cdot}40V_4 + 0{\cdot}75V_5) \quad ...(18)$$

$$F_{tangent} = x(V_3 1{\cdot}1 + V_4 1{\cdot}5) + V_2 0{\cdot}55x + V_5 0{\cdot}75x + \frac{0{\cdot}55^2x^2}{2}\tan\alpha_2 + \frac{0{\cdot}75^2x^2}{2}\tan\alpha_5$$

$$F_{tangent} = x(-0{\cdot}09243V_1 + 0{\cdot}58056V_2 + 1{\cdot}16188V_3 + 1{\cdot}59961V_4 + 0{\cdot}72794V_5 - 0{\cdot}07755V_6) \quad ...(19)$$

$$\Delta F = \frac{2}{3}(F_{tangent} - F_{chord}) \quad ...(20)$$

$$F = F_{chord} + \Delta F \quad ...(21)$$

$$F = x(-0{\cdot}06162V_1 + 0{\cdot}57037V_2 + 1{\cdot}17459V_3 + 1{\cdot}53307V_4 + 0{\cdot}73529V_5 - 0{\cdot}05170V_6)$$

$$F + F_1 + F_2 = x(2{\cdot}31162V_1 - 0{\cdot}20370V_2 + 1{\cdot}47542V_3 + 1{\cdot}60901V_4 + 1{\cdot}14823V_5 + 2{\cdot}15942V_6) \quad ...(22)$$

The water volume Q is estimated by means of the Guldin rule.

$$Q = 2\pi(F + F_1 + F_2)x_{tp} \quad ...(23)$$

According to the Law of Moments and if it is remembered that xa_iV_i represents a certain part of the area $F + F_1 + F_2$, whereupon

$$(F + F_1 + F_2)x_{tp} = x\sum_1^6 a_iV_ix_{tpi} \quad ...(24)$$

If $x_{tpi} = a_{tpi}x$ then x_{tpi} is the C.G. distance to the respective average velocity vector, whereupon

$$(F + F_1 + F_2)x_{tp} = x^2\sum_1^6 a_iV_ia_{tpi} \quad ...(25)$$

TABLE I—WATER VOLUME MEASUREMENT AT THE ..... POWER STATION

Date ..... Test No. .....
Time ..... Gate opening ..... mm.
Running period ..... sec. Runner angle .....°

0°	+	+	+	+	+	+
45°	+	+	+	+	+	+
90°	+	+	+	+	+	+
135°	+	+	+	+	+	+
180°	+	+	+	+	+	+
225°	+	+	+	+	+	+
270°	+	+	+	+	+	+
315°	+	+	+	+	+	+

Σn						
$aa_{tpi}b$	$17{\cdot}33715b^1$	$-1{\cdot}34444b^2$	$8{\cdot}11479b^3$	$6{\cdot}75784b^4$	$3{\cdot}10024b^5$	$2{\cdot}15942b^6$
$aa_{tpi}b\Sigma n$						

$$Q = \frac{A\Sigma aa_{tpi}b\Sigma n}{289t} = \qquad \Delta q_1 = \qquad \Delta q_2 =$$

$$Q_{corr} = Q + \Delta q_1 - \Delta q_2$$

hence $Q = 2\pi x^2 \sum_1^6 a_i V_i a_{tpi}$ ...(26)

But $8{\cdot}5x = R$ from which

$$Q = \frac{2\pi R^2}{72{\cdot}25} \sum_1^5 a_i V_i a_{tpi}$$

then if the measuring area $A = \pi R^2$, is substituted

$$Q = \frac{A}{36{\cdot}125} \sum_1^6 a_i V_i a_{tpi}$$

The mathematical values of the coefficient a_{tpi} may then be used and the following are obtained:

$$Q = \frac{A}{36{\cdot}125}\Big[\, 2{\cdot}31162 \times 7{\cdot}5V_1 - 0{\cdot}20370 \times 6{\cdot}6V_2 + \\ + 1{\cdot}47542 \times 5{\cdot}5V_3 + 1{\cdot}60901 \times 4{\cdot}2V_4 + \\ + 1{\cdot}14823 \times 2{\cdot}7V_5 + 2{\cdot}15942 \times 1V_6 \,\Big]$$

$$Q = \frac{A}{36{\cdot}125}\Big[\, 17{\cdot}33715V_1 - 1{\cdot}34444V_2 + 8{\cdot}11479V_3 + \\ + 6{\cdot}75784V_4 + 3{\cdot}10024V_5 + 2{\cdot}15942V_6 \,\Big]$$

After the terms of $V_1, V_2 \ldots\ldots V_8$ have been substituted as stated above the following is obtained:

$$Q = \frac{A}{36{\cdot}125 \times 8}$$
$$\Big[\, 17{\cdot}33715\ (v_1^1 + v_2^1 + v_3^1 + v_4^1 + v_5^1 + v_6^1 + v_7^1 + v_8^1) - \\ - 1{\cdot}34444\ (v_1^2 + v_2^2 + v_3^2 + v_4^2 + v_5^2 + v_6^2 + v_7^2 + v_8^2) + \\ + 8{\cdot}11479\ (v_1^3 + v_2^3 + v_3^3 + v_4^3 + v_5^3 + v_6^3 + v_7^3 + v_8^3) + \\ + 6{\cdot}75784\ (v_1^4 + v_2^4 + v_3^4 + v_4^4 + v_5^4 + v_6^4 + v_7^4 + v_8^4) + \\ + 3{\cdot}10024\ (v_1^5 + v_2^5 + v_3^5 + v_4^5 + v_5^5 + v_6^5 + v_7^5 + v_8^5) + \\ + 2{\cdot}15942\ (v_1^6 + v_2^6 + v_3^6 + v_4^6 + v_5^6 + v_6^6 + v_7^6 + v_8^6) \,\Big]$$

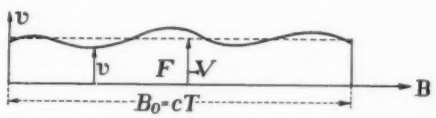
If the current-meter equation $v = a + b\,\frac{n}{t}$ is substituted except for the friction constants, the following is obtained:

$$Q = \frac{A}{289t}$$
$$\Big[\, 17{\cdot}33715\ b^1 (n_1^1 + n_2^1 + n_3^1 + n_4^1 + n_5^1 + n_6^1 + n_7^1 + n_8^1) - \\ - 1{\cdot}34444\ b^2 (n_1^2 + n_2^2 + n_3^2 + n_4^2 + n_5^2 + n_6^2 + n_7^2 + n_8^2) + \\ + 8{\cdot}11479\ b^3 (n_1^3 + n_2^3 + n_3^3 + n_4^3 + n_5^3 + n_6^3 + n_7^3 + n_8^3) + \\ + 6{\cdot}75784\ b^4 (n_1^4 + n_2^4 + n_3^4 + n_4^4 + n_5^4 + n_6^4 + n_7^4 + n_8^4) + \\ + 3{\cdot}10024\ b^5 (n_1^5 + n_2^5 + n_3^5 + n_4^5 + n_5^5 + n_6^5 + n_7^5 + n_8^5) + \\ + 2{\cdot}15942\ b^6 (n_1^6 + n_2^6 + n_3^6 + n_4^6 + n_5^6 + n_6^6 + n_7^6 + n_8^6) \,\Big]$$

The small loss of water volume caused by the friction constants a, and which is shown in Table I as Δq_1, being constant for all tests, can easily be calculated, as shown in the preceding article, when the friction constants are entered in the table. In this case, the edge correction has also been denoted by Δq_2 and is calculated as before.

The coefficients in the table are shown turned at an angle of 90°, and the symbols representing the number of revolutions n omitted. In this way a useful practical calculation table is obtained, applicable to 6 current meters and 8 current-meter positions.

If integration measurement is to be used, the equation $V = a + b\,\frac{N}{T}$ is applicable to each current meter, where V consequently indicates the average velocity vector for each revolution that the current-meter body is turned round at the constant rate c, a indicates the friction constant, b the lifting, N the number of revolutions made by the current meter when the rod has completed one revolution, and T the number of seconds for one revolution of the rod. This formula is perhaps not quite self-evident, and therefore it is derived as follows:



$$V = \frac{F}{B_0} = \frac{\int v\,dB}{B_0}$$

$$v = a + b\,\frac{n}{t} = a + b\,\frac{dn}{dt}$$

$B = ct$ where c = constant = current-meter velocity in metres per sec.

$dB = cdt$

$B_0 = cT$

$$V = \frac{\int \left(a + b\frac{dn}{dt}\right) cdt}{cT} = \frac{a}{T}\int_0^T dt + \frac{b}{T}\int_0^N dn$$

$$\therefore V = a + b\frac{N}{T}$$

Here the calculation table will be simplified to:

N						
$aa_{tp}b$	$17{\cdot}33715b^1$	$-1{\cdot}34444b^2$	$8{\cdot}11479b^3$	$6{\cdot}75784b^4$	$3{\cdot}10024b^5$	$2{\cdot}15942b^6$
$aa_{tp}bN$						

$$Q = \frac{A\sum aa_{tp}bN}{36{\cdot}125T} = \qquad \Delta q_1 = \qquad \Delta q_2 =$$

$$Q_{corr} = Q + \Delta q_1 - \Delta q_2$$

As may be appreciated, a special case has been treated here. Unfortunately, it seems impossible to obtain a calculation table of such a general type as that for the rectangular measuring area. However, most ordinary penstock areas can be managed by means of 10-15 formulae of this type, and therefore this limitation is scarcely of any practical importance. In Fig. 1 an outline has been given of current-meter positions likely to be suitable and applicable to penstock diameters from about 1,000 to 5,500 mm., in order to facilitate the derivation of new formulae. The number of current-meter positions should, of course, be increased with the penstock diameter, but it will not be necessary to have any pattern of this, due to the very simple connection prevailing in this case. Though this method is not yet practically tested, it will still be clear that quite like the method treated in the preceding article, much time can be gained by using this counting diagram instead of curve drawing and planimetration.

It is also possible to derive a similar formula in other ways, for example using only parabolae, but the author cannot say which formulae is most accurate.

Calculating Flow Through Turbines.—Mr. Andersson has drawn our attention to one or two typographical errors in the second instalment of this article which appeared in our July issue. The frequency diagrams for Figs. 6 and 10 were inadvertently transposed and should be interchanged. In the heading to Table V, $v_m - v_m$ should read $\bar{v}_m - v_m$, and v_m should read $\bar{v}_m$ on page 270, col. 1 line 9 and col. 2 line 1, and on page 271 col. 2 line 35. In line 26 of this column, 0·2 should read 0·02. We must offer our apologies for these discrepancies.

From page 372

late the future impervious blanket on the main dam has been built and is under observation for pore pressure, settlement, etc. Her Majesty's Colonial Surveys have prepared air-survey maps of the whole of the reservoir area and the Aircraft Operating Company has photographed and mapped the dam site and many miles of transmission route. It will be recalled that a very large hydraulic model of the river was built by the Consultants in London in 1954 and some details were given in WATER POWER, March 1955, p. 98.

Details are also given of an additional future development of the Volta at the Bui Gorge. Here the erection of a buttress dam is proposed together with an underground power station rated at 65 MW continuous with an installation of 120 MW. Provision is made for an additional set at some future date of 40 MW capacity. The electricity generated at Bui would be delivered by 140 miles of transmission lines to Kumasi, at which point it would be fed into a ring grid proposed by the Consultants. The grid would also be supplied from Ajena and any thermal stations which happen to be in existence at the time.

The mineral railway linking the bauxite deposits with the smelter and the railway between the smelter and the new Port of Tema has also been surveyed and estimates of construction and operation costs given. It includes the improvement of about 160 miles of existing railway and about 83 miles of new railway.

In order to keep the people of the Gold Coast informed, a very large travelling exhibition including models, relief maps and other exhibits, has been touring the Gold Coast for some considerable time.

It will be seen, therefore, that practically all the preparations which can reasonably be made for the successful construction of this very large scheme have been conscientiously undertaken. It now remains for a resolution of the political and economic details to be achieved, and it is hoped that the latest outbreak of unilateral activity at Suez will not hamper future discussions on the Volta project.

High-Power Short-Circuit Testing Station. This is the third edition of a descriptive brochure published by Switchgear Testing Company Ltd., Trafford Park, Manchester, a member of the AEI Group operating on behalf of The British Thomson-Houston Co. Ltd., Ferguson Pailin Ltd., and Metropolitan-Vickers Electrical Co. Ltd. The testing plant commenced operation in 1934 with one test generator, one three-phase 132 kV bank of transformers, and two test bays. Now it is equipped with three test generators, three 132 kV three-phase banks of step-up transformers, one three-phase step-down transformer, and a chain of single-phase transformers for producing single-phase test voltages up to 323 kV. When extensions now in progress have been completed, the output of the station will be increased and the three-phase testing facilities will be extended to 275 kV.

Fig. 8. The completed Ben Métir dam showing the stilling basin in the foreground

The Ben Métir Dam

Some difficult design problems were posed in this Tunisian development by the unsatisfactory nature of the terrain. These articles explain in detail how these problems were solved

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PART TWO

THE short description of the terrain given in the previous article made it clear that the problem of foundations was difficult. On the other hand the site presented two important favourable features: the upstream dip towards the left bank, where the marls were most weathered, and the pronounced and progressive improvement in the quality of the marls across the site in the direction of the right bank.

The subsoil was explored by a large number of boreholes, 100 mm. in diameter, as well as by pits from which specimens of various beds of marls and sandstones were taken and submitted to laboratory tests. Once the decision had been taken to locate the buttresses on the marls and not on the sandstones, the marls were studied with the greatest care. Leaving the weathered marls out of account, the water content varied from 5 to 11 per cent., the plastic limit from 14 to 22 per cent., and the index of plasticity from 11 to 21 per cent. Cube crushing tests, to which overmuch importance was not attached, gave resistances reaching 70 kg. per sq. cm. and in exceptional cases 150 kg. per sq. cm.

The information most vitally required was the resistance to sliding, not only of the concrete on the marl, but of the marls on one another. Further, the borings had revealed the presence of more-plastic but relatively thin layers, and the risk of more or less adjacent layers of this type at depth forming a sliding plane had to be taken into account. The angle of internal friction of the marls varied within wide limits (from 40° to 25° with a corresponding cohesion of 8 to 0·3 kg. per sq. cm.). From the standpoint of stability against sliding, the buttresses were therefore dimensioned on a basis of an angle of friction of 25° and a cohesion of 0·3 kg. per sq. cm. It was also arranged that even if a more or less continuous sliding layer appeared at depth (although in fact no such layer was found to occur) the stability on this plane would be ensured for an angle of internal friction of 11° without any cohesion.

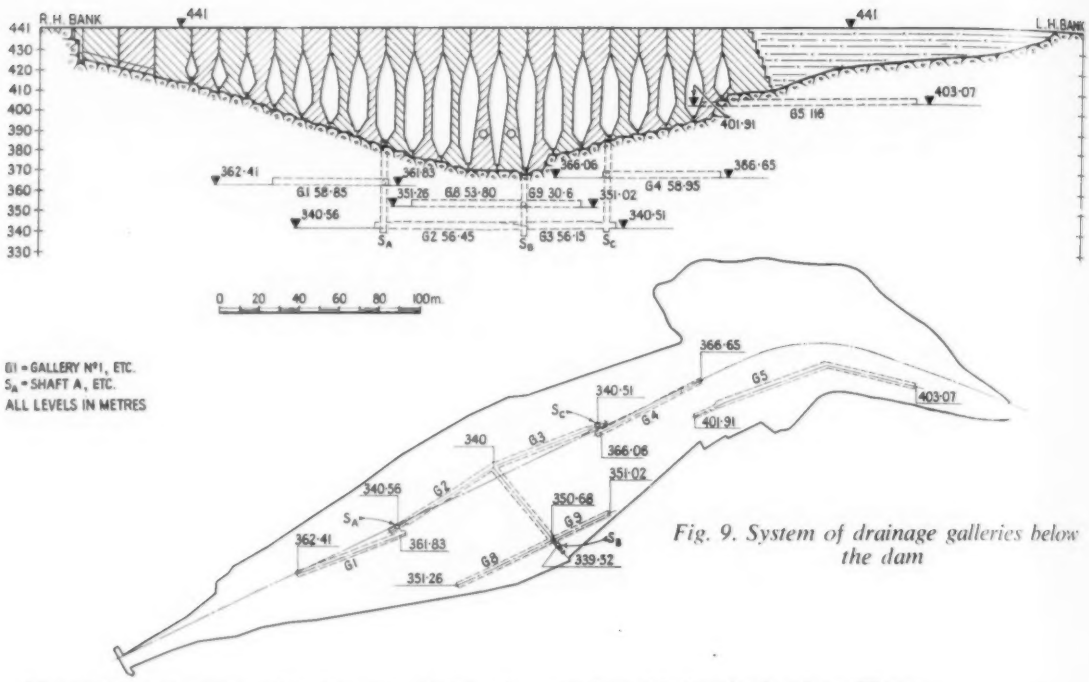

Fig. 9. System of drainage galleries below the dam

Seeing that laboratory shearing tests had to be treated with reserve in view of the heterogeneous character of the terrain and the restricted size of the test specimens, it was decided to check them by a large-scale test on the actual terrain. For this purpose buttress No. 13 was chosen, as its foundation appeared to be the least satisfactory. A large chamber was left in the base of this buttress, in the centre of which a concrete block was placed, 5 m. long, 3 m. wide and 2·5 m. high. Once the tests had been completed the cavity was concreted solid.

A load N (Fig. 10) normal to the foundation surface and ranging from 0 to 1,250 tons, was imposed on this block by four Freyssinet flat jacks bearing against the buttress structure. From the upstream direction a force P, parallel to the foundation and ranging up to 1,695 tons, was imposed by two further flat jacks. Finally, two other flat jacks located at the downstream end between the test block and a distribution block measured the abutment reaction B. Vertical and horizontal displacements were measured by twelve gauges graduated in hundreths of a millimetre.

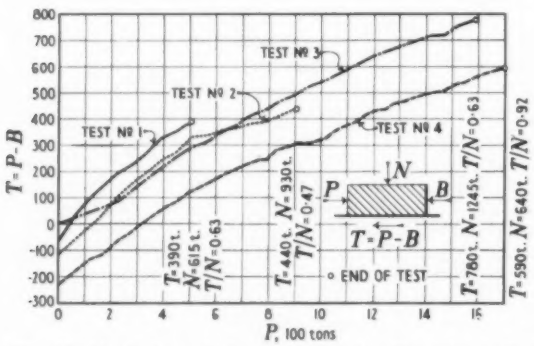

Fig 10. Variation of shearing reaction T *with applied force* P

The tests consisted of first applying, normal to the foundation, a load corresponding approximately to that obtaining with the reservoir empty, and allowing one or two days to elapse to enable the ground to become partially consolidated. Then the load was increased to that corresponding to a full reservoir, and the actual shearing test was conducted by imposing a horizontal force P by means of the two upstream jacks. For each value of P the downstream jacks, which had previously been placed under pressure and connected to manometers, indicated the corresponding abutment reaction B, from which the tangential reaction on the ground, $T = P - B$, could be determined. Each test was stopped when T ceased to increase with P. To avoid disturbing the ground the tests were not carried to the point of rupture, so that the shearing force measured was actually less than that which the ground could have withstood. Four tests were carried out with different values of forces and of periods of consolidation.

For the first test the pressure on the foundations was 30 tons per sq. m. and was maintained for about 40 hours. During the first few hours the settlement increased rapidly, but was very slight during the last two hours. For the other three tests the period of consolidation was reduced, as settlement was very slight. Thus, in spite of the relatively small dimensions of the test block, the periods allowed for consolidation were extremely short, so that the degree of consolidation attained during the tests was significantly less than that attained below the buttresses when the reservoir was filled—a factor conducing to safety.

Fig. 10 shows the variation of shearing reaction T with sliding force P. The maximum values of T given in this diagram are less than the actual resistance because the tests were prematurely interrupted. The values of the normal compression N corresponding to these maximum values of T are also indicated. For

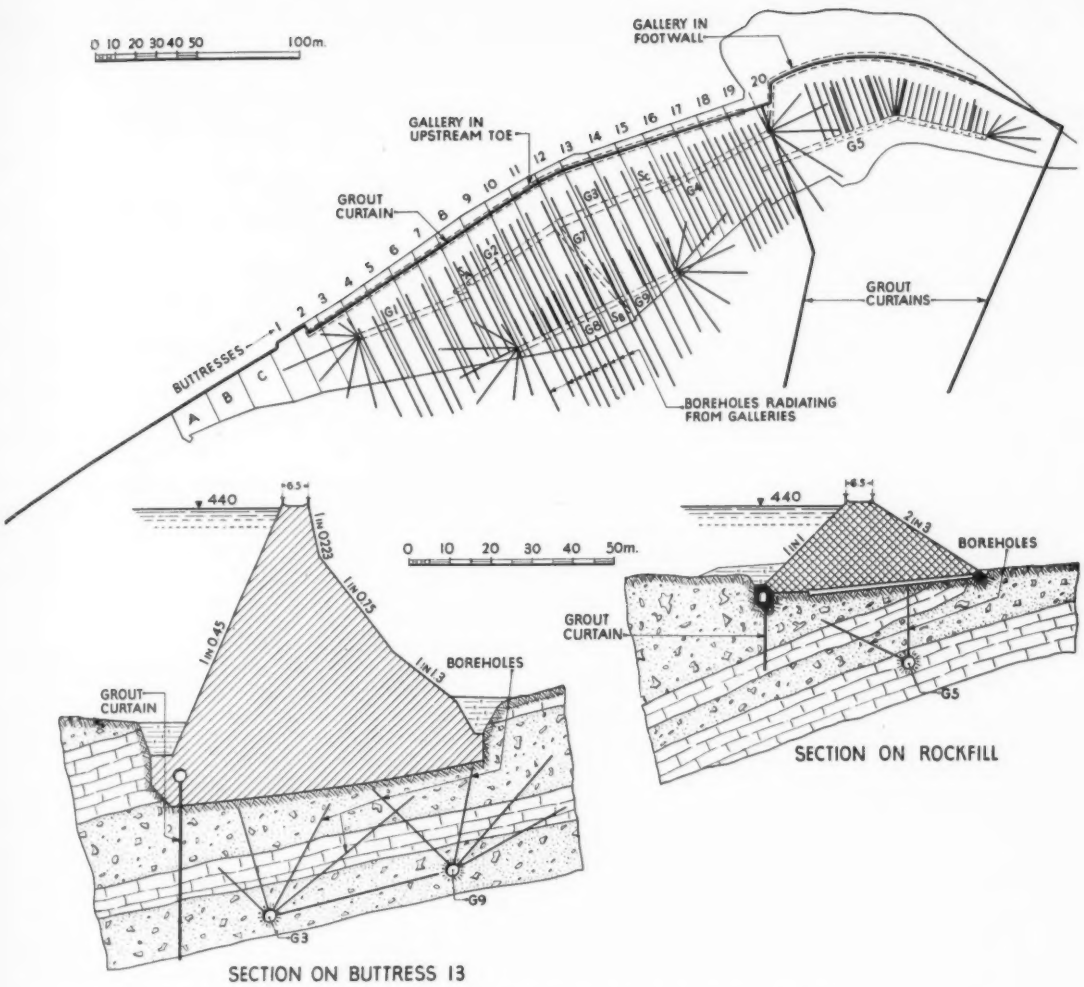

Fig. 11. System of grouting and drainage boreholes below the dam

tests Nos. 1, 3 and 4 the values of the ratio T/N were found to be much higher than those determined by laboratory tests, whereas the value given by test No. 2 was slightly below the laboratory result. Consequently the cohesion figure was reduced to 0·1 kg. per sq. cm. although the angle of internal friction was retained at 25°.

Drainage System

An essential feature of the project was the construction of an underground drainage system. This is extensive and was put in to expedite the consolidation of the marls under the load imposed by the dam under full-reservoir conditions and to increase and maintain their shear resistance by draining out the interstitial water.

Figs. 9 and 11 show the positions of three shafts and seven galleries which were excavated before the buttresses were built. Radiating from these galleries a series of boreholes was driven to depths ranging from 20 to 40 m. underneath the entire site of the buttresses and of the left-hand rockfill section. These boreholes, which are lined with perforated Lucoflex tubing, have an aggregate length of 14,700 m. They are never under pressure, as the drainage water is led by the galleries to a well in the valley bed 35 m. below the foundations, whence it is removed by two pumps.

A further objective of this drainage system was to encourage a preliminary consolidation of the foundation rock before the dam was completed, and in fact appreciable settlements were observed both before and during the concreting of the buttresses.

The marls were practically impervious but, as already mentioned, the sandstones were very porous, and underground seepage had to be prevented by means of a grout curtain. For the most part this was put down from the galleries in the upstream toe of the buttress section and of the rockfill section. On the wings the grout holes were drilled from outside the dam. On the right wing the curtain was extended 120 m. beyond the dam, whereas on the left wing the dip of the sandstone beds and their outcropping downstream of the rockfill section necessitated the injection of two grout curtains running downstream from the

rockfill so as to cut off all direct communication between upstream and downstream of the dam by way of the sandstones.

To prevent seepage between the concrete and the rock, further radiating boreholes and sealing injections were executed in addition to the grout curtain proper.

Flood Control and Reservoir Drainage

In view of the argillaceous nature of the terrain, the structures for the evacuation of floods and for the emptying of the reservoir are of particular importance from the standpoint of the safety of the dam. Any overtopping could have serious consequences, and these constructions had therefore to be dimensioned to cope with the worst predictable flood entering a full reservoir. Furthermore, it was desirable to be able to control the rise of water level as completely as possible during the initial filling of the reservoir even if a heavy flood occurred during this period. This meant that a large discharge capacity would have to be available even at intermediate levels; a simple spillway, even of large dimensions, together with a normal emptying culvert, would not suffice. Finally, to avoid undermining the feet of the buttresses, the water had to be returned to the river bed some considerable distance downstream, and after most of its kinetic energy had been dissipated.

The Ben Métir dam is equipped with two bottom-emptying culverts, each capable of discharging 185 cu. m. per sec., and a circular spillway consisting of a shaft, with sill level at 425 m., surmounted by a cylindrical gate, 15 m. high, capable of discharging 620 cu. m. per sec. By this arrangement a discharge of 850 cu. m. per sec. is possible when the reservoir is 10 m. below its maximum level, and the discharge rises to 990 cu. m. per sec. when the reservoir is full, at 440 m. The maximum predictable flood corresponds to a mean daily flow of 260 cu. m. per sec. and a maximum instantaneous flow of 1,150 cu. m. per sec., and if the 4 million cu. m. reservoir capacity between normal top-water level, 440 m., and crest level, 441 m., be taken into account, it can be calculated that an instantaneous flow of 1,400 cu. m. per sec. can be absorbed without overtopping the dam.

All the culverts discharge into a stilling basin 200 m. downstream of the dam.

Bottom-Emptying Culverts

The two bottom-emptying culverts, which, as described in the previous article (see Fig. 6), are carried in the central buttresses, are identical but are independent. From upstream to downstream each is equipped with a wide-mesh reinforced-concrete grid covering a bellmouth entry, an emergency gate, a steel-plate conduit 3 m. in diameter and 65 m. long, and a sector-type regulating gate at the downstream foot of the buttress. The water then flows through a free-flow culvert, curved in plan, to the stilling basin. The sill level at culvert intakes is 390 m., which is 50 m. below the normal retention level and 10 m. above river bed.

The emergency gates are of the roller type, 3 m. by 5 m., and are operated by servomotors in watertight reinforced-concrete chambers built on the upstream face of the dam below sill level. These gates permit maintenance work on the steel culverts and the sector gates to be carried out, and can themselves be overhauled from a platform built out from the upstream face at 428 m. after successive disconnection of the link rods connecting the gates to the servomotors. An air vent, 80 cm. in diameter, which emerges at crest level, permits the escape of air from either culvert when the corresponding emergency gate is opened—an operation which is performed only when the sector gate is closed—and also prevents suction when the emergency gate is closed against running water.

The sector gates are located in chambers at the feet of the corresponding buttresses. They measure 2·4 m. by 2·6 m. and can be operated against running water whatever the reservoir level. A 60 cm. diameter conduit, fitted with a disperser valve at the downstream end, bypasses the culvert in No. 11 buttress to provide small river flows without operating the main sector gates.

The free-flow culverts leading to the stilling basin are laid in the old river bed. They are constructed in plain concrete and are buried in spoil from the excavations; this spoil forms an abutment for buttresses 11 and 12. The profile of these culverts was studied by model tests to discover the influence of their curvature in plan on the flow, which may attain 30 m. per sec., and it was found advantageous to tilt the floor to avoid the risk of the sheet of water placing the culvert under pressure.

Circular Spillway

The circular spillway, Figs. 12 and 14, consists of a shaft 6·4 m. in diameter, with sill at 425 m., surmounted by a cylindrical gate, 15 m. high. This gate is connected by six chains to a 120 ton central concrete counterweight, the overbalance being in the direction of opening. The chains pass over a winch located in a winch house at the top of the structure at 450 m.

When the reservoir is full the gate opening is controlled automatically by the water level by means of a float in one of the piles supporting the access gangway, but this automatic control is limited to a flow of about 300 cu. m. per sec. to enable the dam attendant to distribute heavy flood flows between the spillway and the bottom-emptying culverts so that the flow into the stilling basin is not too asymmetrical. The spillway shaft is drowned when the flow exceeds 550 cu. m. per sec.

The spillway shaft is followed by an elbow succeeded by a discharge culvert 6 m. in diameter. Immediately downstream of the elbow a constriction in the ceiling induces a change from pressure to free flow. (In the argillaceous terrain at Ben Métir it is, in fact, unwise to place any buried culvert under pressure). The culvert then joins the old diversion gallery, which finally curves sharply to discharge into the stilling basin. Over this curved section the gallery is partitioned vertically by a guide vane to interfere with the deflection of the water sheet by centrifugal force.

Stilling Basin

The stilling basin has to dissipate the kinetic energy of the water and to do so without risk of eroding the river banks whatever the amount and distribution of the discharge. On the other hand, to reduce the size and the cost of the basin as far as possible, it was decided to dimension it for a maximum flood of only 600 cu. m. per sec.—representing 300 cu. m. per sec. from the bottom-emptying culverts and 300 cu. m. per sec. from the spillway—and to accept partial dis-

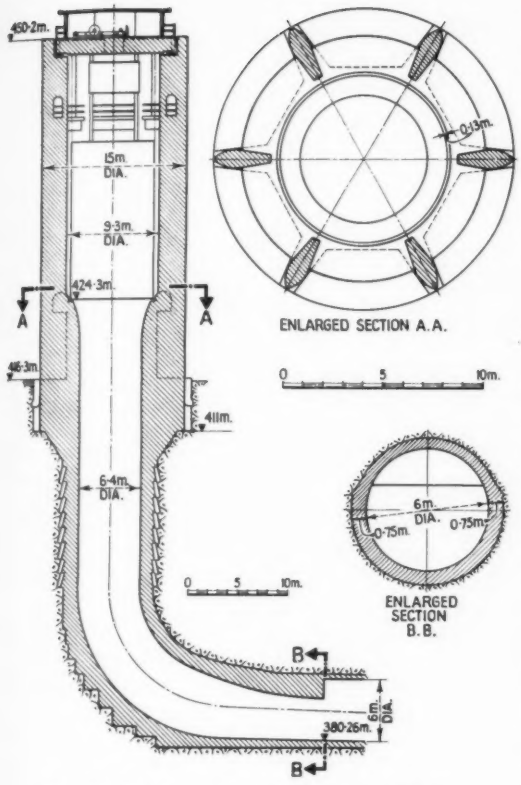

Fig. 12. Sections through circular spillway

sipation for floods reaching 990 cu. m. per sec. from the three culverts or 620 cu. m. per sec. from the spillway acting alone.

As the basin was excavated in the river bed itself, in argillaceous terrain, it could not be made very deep without jeopardising the stability of the banks, which were already subject to landslides before the commencement of the works. On the other hand it was desirable for the water level to remain sufficiently low at the upstream end to avoid placing the culverts under pressure and flooding the spoil forming the abutment for the buttresses.

These problems were made the subject of model tests, at a scale of 1 : 50, carried out at Lausanne University. The resulting design (Fig. 13) comprises two successive basins separated by a weir designed to produce a hydraulic jump in the upstream basin. This basin is constructed in unreinforced concrete and is 65 m. long and 20 to 25 m. wide, subdivided by numerous joints to enable it to adapt itself to eventual ground movements. The floor rises in steps from upstream to downstream to induce the hydraulic jump.

The side walls are subdivided by ribs which have the double purpose of strengthening the side walls and of inducing lateral eddies which check the circulating currents formed when the flow from the culverts is asymmetric. Between these ribs the side walls take the form of small arches to resist the earth pressure. Rows of gabions disposed staircase-fashion on the two banks and covered at the bottom by concrete slabs, complete the protection of the banks, which are also drained through holes bored horizontally through the gabions from their tops. To prevent uplift pressures, circular holes filled with gravel have been made in the floor of the basin, which rests on a bed of porous concrete.

The stilling-basin spillway induces a hydraulic jump whatever the water level in the river. It takes the form of a small overflow dam pierced by two orifices, 3 m. in diameter, to prevent the establishment of too high a water level in the basin at times of low discharge and thus avoid the danger of drowning the culverts.

Behaviour of the Dam and its Foundations

Concreting of the buttresses was commenced in August, 1950, and completed in December, 1953, although work on ancillary structures and the rockfill wing continued until the winter of 1954-55. In the course of the winter 1953-54 the reservoir was partly filled, to a level of 426 m., the stage of construction not having permitted the first floods of the season to be impounded.

The settlements of the buttresses and of the rockfill wing were measured periodically by precision levelling. For this purpose sighting marks were let into the crest, along the length of the foundation plinth of each buttress, in the upstream gallery, and on the downstream toe of the rockfill embankment. Thus it has been possible to measure the settlements occurring since the beginning of the construction of the buttresses without the results being greatly influenced by temperature variations, which would be the case if the sighting marks had been confined to the crest.

The maximum settlements observed at the feet of the highest buttresses since measurements were commenced in the summer of 1951 were about 5 cm. at the upstream and 7 cm. at the downstream toe in the spring of 1955. These settlements increase most rapidly in the spring, when the reservoir fills, and tend to be arrested as the reservoir empties, but have not yet become stabilised. This is normal, as the maximum load has not yet been reached and consolidation is progressive. The settlements are systematically larger at the downstream than at the upstream toe although the load there is less. This is because the drainage system is more extensive at the downstream end, whereas the upstream foundation is consolidated by grouting.

Horizontal displacements of the buttresses are measured by triangulation and by two plumb bobs suspended in the access shafts to the drainage galleries. Since the filling of the reservoir in 1954-55, downstream displacements of the order of 7 mm. have been observed in the case of the highest buttresses.

Levelling and triangulation measurements are long and delicate operations which it is practical to carry out only at intervals of many months, and to keep the dam under continuous observation, especially while the reservoir is filling, and in particular to detect any relative movement between adjacent buttresses, which would deform the water seals, three sighting marks have been inserted astride each joint at the crest, the upstream foot, and the downstream foot, forming an equilateral triangle. Measurement by dilatometer of variations in the lengths of the sides of these triangles reveals any opening of the joints or relative displacement of the lips.

These measurements have shown that sliding between joints has remained very small, and has not exceeded 1-2 mm. either horizontally or vertically.

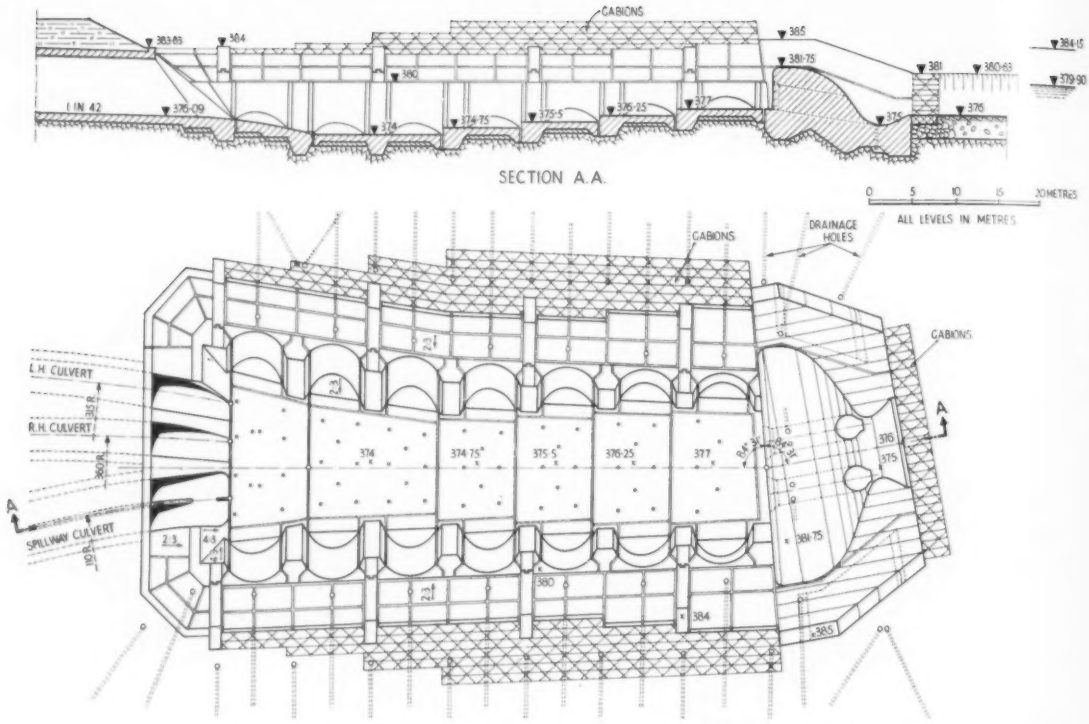

Fig. 13. Sectional elevation and plan of the stilling basin

The differences in settlement from one buttress to another therefore do not arise from an abrupt displacement across the joint but from internal deformation of the foundation plinth, which behaves more or less as a continuous foundation. As the joints are obviously the sections of least resistance, this shows that the load distribution on the foundations must be fairly evenly graded.

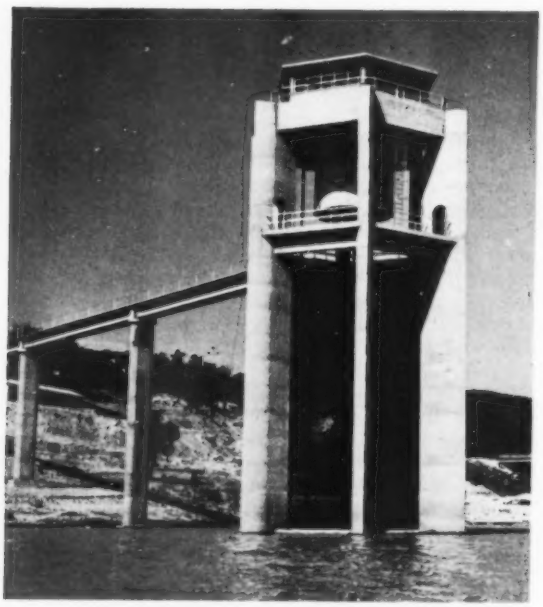

Fig. 14. The circular spillway

To check the degree of consolidation of the ground and the efficacy of the drainage system, the discharge from the drains is measured and also the interstitial earth pressure, the latter by piezometric capsules. Up to the moment the total discharge from the drains varies very little—from 2 to 3 litres per sec.—whereas when the shafts and galleries were excavated in 1950 the discharge totalled 4 to 6 litres per sec. This reduction in discharge in spite of the partial filling of the reservoir indicates that a state of equilibrium is in prospect after an initial drying out of the marls.

Numerous piezometric capsules have been located in the boreholes at depths ranging from 1 to 20 m. below foundation level. Generally speaking, the interstitial pressure varies only slightly; it increases slightly at each reservoir filling and subsequently falls again.

In conclusion, the various measurements show that the dam is behaving satisfactorily. The settlements of the buttresses, although appreciable and not yet entirely stabilised, are of the order expected. The initial partial reservoir fillings have not given rise to any abnormal horizontal displacements.

The consulting engineers for the Ben Métir dam are Direction des Travaux Publics de Tunisie, the successive directors being first M. Bonenfant and then M. Mathieu. The chief engineers were successively M. Marty and M. de Montmarin. The contractors were Entreprises Campenon Bernard, of Paris.

NOTE: The substances of this article originally appeared in French in *Bulletin Technique de la Suisse Romande*, and the English article has been prepared in collaboration with the author.

The World Power Conference 1956

In this second article of our series reviewing the Vienna Conference we discuss international co-operation in power matters, the design, construction and operation of hydro-electric plants, and the growing importance of pumped-storage systems in mixed interconnected systems

PART TWO

THE section of the Conference dealing with the application of statistical methods to fuel and power economies was presided over by the President, Sir Harold Hartley, the General Reporter being Professor Schmetterer, of Vienna University. He said that the efficiency of water-power plants could be considerably increased by continued technological improvement, but in the last resort optimum economic exploitation depended mainly on the reliability of the hydrological data and their expert interpretation. Statistical methods, even in more recent analyses, had still maintained their purely traditional character, whereas, until now, modern developments in statistics had barely penetrated the field of hydrology.

Hydrological Statistics

The papers showed that hydrographs, or systems of hydrographs in the case of an unstable profile, do not always reliably reproduce the relationship between the water table and the run-off. The substitution for the hydrograph of a "correlation range" was suggested (this, in the terminology of statistics, being defined as a confidence belt for the hydrograph as determined from observed data) and was stated to be completely in line with the concepts of modern statistics. The correlation range could be determined by means of hydrological analysis. From the point of view of statistical method it was said that it would be preferable to construct a "distribution-free confidence belt" for the hydrograph which would be valid for any assumption concerning the underlying distribution; and moreover would allow an accurate statement to be made of the probability (which might reach 99 or even 99·9 per cent.) that the theoretical relationship curve between water table and run-off would fall within this confidence belt.

The need for international directives in the compilation of water-power surveys was stressed in both the papers and the discussions, and it was hoped that the World Power Conference would help in providing uniform world fuel and power statistics. Among the many detailed points arising in connection with this proposal, there was a recommendation that the numerous mean values given in hydrological data should always be supplemented by a statement of the limits of scatter, which were often very wide. A proposed questionnaire, to be circulated to all members of the World Power Conference, was discussed, and the suggestion was universally commended.

There was some considerable argument about the concept of linear potential and its relationship to surface potential. It was stated that since hydro plants were usually built along the principal rivers, a most appropriate method of assessing gross potential would be to determine this in terms of the run-off along each stream, this being the linear-potential method. In the case of surface potential, the available power was determined on the basis of annual precipitation.

The suggested subjects for discussion set out by the General Reporter included the desirability of closer co-operation between statisticians and hydrology experts, with a view to bringing methods of evaluating statistical data into closer co-ordination with recent mathematical practice.

This session was also concerned with means for evaluating future demands for electrical energy, and here the papers and the discussions showed very considerable variants in the forecasting methods adopted in different countries. Two trends, however, could be distinguished: First, there were those who relied on overall surveys based on a mean annual incremental rate of fuel and power demand, and secondly, others who conducted separate analyses of sectors of demand, including the industrial, agricultural, transport and domestic fields of utilisation, and then summated the figures obtained. It was considered that both these were capable of improvement, but the discussion did not reveal any significant alternatives.

The discussion in this section was somewhat disappointing as, in general, the broader aspects of the subject were neglected, the emphasis being on purely local methods employed for load forecasting and the assessment of hydro-electric potential.

International Co-operation in Power Development

It is convenient here to make some brief reference to the proceedings under Sections N and O, dealing respectively with the technical and economic aspects of international co-operation in the production and use of energy. In both these sessions, the papers showed a greatly increased interest in the inter-connection of the power systems of different countries. The pattern of international development of waterways may be considered under two headings: rivers which form the boundary between two countries, and those which run from one country into another. In the first case international development appears to pose few problems, since the interests of the two countries are parallel, and the exploitation of the water power, navigational, and flood control measures do not usually give rise to international problems.

However, in spite of the instances given in the papers where such developments as the Upper Rhine and the Danube have been carried out with international co-operation, there are other cases, such as the St. Lawrence River on the frontier between Canada and the United States, where the discussions on the proper exploitation of the waterway had lasted for some decades.

In the case of the second type of shared water, more difficult problems may arise. Instances given in the papers included the Rhône, which after leaving Lake Geneva flows from Switzerland into France; or the River Drau, which crosses from Yugoslavia into Austria. If the plans of the two nations can be so co-ordinated that the successive reservoir stages form a virtually unbroken chain, the development can be carried out to maximum mutual benefit, and in the two cases cited this has been possible.

The General Reporter in Section O, Dr. Vas, of Vienna, asked whether the principle of territorial sovereignty could still be upheld, in the sense that any one country might consider it feasible to dispose of water without consideration for a downstream country on the same river. He suggested that international relations should be based on the principle of integration, that is to say, a watercourse should be considered as an economic entity. The papers showed that this principle had already been adopted in arrangements made between Austria and Germany, and other countries in Europe.

In the discussions Yugoslav representatives stressed that their water-power resources should be developed as soon as possible, and that the power available should be utilised over the whole of south-eastern Europe.

Influence of Super Grids

Mr. Melvin, a consulting engineer from the United States, stated that grid operation in the U.S.A. was expanding rapidly, and he thought that in a few years' time a super grid would extend over the whole country, thus enabling water-power resources to be integrated completely with thermal stations, and with the nuclear plants of the future, with resulting overall economy and dependability.

The Austrian delegates, in Sections N and O, said that they felt a special responsibility, as their country was in the centre of Europe and had very considerable reserves of undeveloped water power. They urged that every effort should be made to co-ordinate and develop power production and utilisation on an international basis.

In this connection—to digress for a moment—mention may be made of the generous gesture of the Austrian National Committee of the World Power Conference in providing for each delegate a magnificent set of four large books containing a summary of the present power position in the world today, country by country, under the general title of "Energy Today."

These valuable reference volumes were exceedingly well received by the delegates, who were also presented with the June issue of the *Oesterreichische Zeitschrift fuer Elektrizitaetswirtschaft*, which contained a series of articles on subjects related to the Conference proceedings, and which, in many cases, complemented and augmented the information given in the papers. In particular, there was in this issue a valuable article on Russian energy developments, and a detailed description of the "Interalpen" and a "Yougelexport" plans, the first relating to the complete electrical interconnection of the Alpine hydro-electric resources in Germany, Austria, France and Italy, and the second, with which Germany, Austria, Italy and Yugoslavia are concerned, relating to the development of Yugoslav water power for European use.

Design of Hydro-Electric Plants

We turn now to those two sections of the Conference which are of the most direct interest to hydro-electric engineers—Section H.1 on the Theory and Design of Hydro-electric Plants, and Section H.2 on their Construction and Operation. For both of these sections extremely comprehensive General Reports were prepared by Dr. Anton Grzywienski.

In the section on the Theory and Design of Hydro-electric Plants, 44 papers from 22 countries were presented. Grzywienski first commented on the fact that little reference was made in the papers to progress in the auxiliary sciences of special interest to hydro-electric engineers, such as hydraulics, structural analysis, strength of materials and geology. There was, however, a paper from Dr. Kastner, of Austria, on the problems of rock mechanics. The author stressed the effect of what is generally known as rock pressure, and he applied to the elucidation of the problems arising from this phenomenon a new theory of "plastic zones." He touched on the construction of the linings of pressure galleries and shafts, and on the methods of designing these structures from the viewpoint of elasticity. The theory of their design was also elaborated.

The General Report showed that scarcely any hydro-electric plant of any size is nowadays built without hydraulic models being constructed. The employment of extensive hydraulic research by manufacturers was the subject of a paper by Mr. Braikevitch, of the English Electric Company, who described the Company's research equipment installed at the Rugby works. This was seen to include two berths for cavitation research, which enabled a head of 95 ft. to be employed. The two berths for impulse turbine tests had a water head of 160 ft., and a berth for high-head reversible pump-turbines was also available.

The use of photo-elastic methods for checking the structural analysis of various types of dam structures is being more widely accepted. In a paper by Ing. Steinböck, of Austria, some striking illustrations showed the stress distribution lines in a hollow structure, and the difference in these lines in a solid structure of the same general outline.

Advantages of Underground Stations

The first section of the hydro-electric sessions contained a number of papers on the economy of water-power schemes, and legislation covering the general utilisation of water. One of the trends noticed in these papers, particularly in those from Norway and Sweden, was towards the increasing use of underground installations. For example, Mr. Heggstad, of Norway, said that during the years after the war a most intensive programme of hydro-electric development has taken place in Norway, and of the 56 new

power stations built since 1946, twenty-four of the largest had been placed underground. Both the stations themselves and the pipelines were constructed in the rock, and the main reasons why this procedure was considered economic were:—

1. Better utilisation of heads, and under unfavourable ground conditions, greater possibilities and elasticity in the choice of site and type of plant.
2. Shorter pipelines, which is a factor of special importance with high heads and large pipe diameters. Hydraulic losses have also been considerably reduced. Where pressure shafts in rock have been used, a further saving has been attained in regard to the weight of steel needed.
3. Better protection against avalanches and falling rocks.
4. In dry, good rock, constructional details, such as pillars, walls, foundations and crane girders can be considerably simplified as compared with stations in the open.
5. Maintenance and repair costs, which may be considerable in plants sited in unfavourable climatic conditions, are greatly reduced.

There were a number of papers dealing with the functions of lakes in regulating the whole of a hydraulic system. In particular, Mr. Castrén, of Finland, described in detail how seven regulation schemes have made it possible to store 11,248 million cu. m. of water, equal to 1,411 million kWh of energy. This is equivalent to 27·2 per cent. of the annual generation of all the water-power stations in the country. It is hoped that within about ten years the storage in these lake-reservoirs can be increased to 43·5 per cent. of the total energy requirement at that time, which will then reach about 11 milliard kWh. This tendency to increased storage and regulation was mentioned in many other papers.

Pumped Storage

An interesting paper came from three British engineers, Messrs. A. A. Fulton, of the North of Scotland Hydro-electric Board, T. G. N. Haldane, of Merz and McLellan, and R. W. Mountain, of Kennedy and Donkin. In it they described the practical application and economics of pumped storage in Great Britain. They stated that progress in the application of hydro-electric pumped storage had been slow in Great Britain compared, for example, with the Continent, where about a million h.p. of pumped storage plant was in use, with heads varying from 33 ft. to some 3,000 ft. This had not been due so much to any failure to appreciate the value of pumped storage, but more to the doubt whether, in the circumstances of the past, the schemes studied had economic merit. In the circumstances now operating, however, it had been recognised that a properly chosen scheme could be of much economic advantage to the electricity supply system. Both the Central Electricity Authority, covering England and Wales, and the North of Scotland Hydro-electric Board had initiated studies of possible schemes, a number of which had been found attractive. One scheme which has been adopted and was approaching completion is the North of Scotland Hydro-electric Board's 5 MW plant at Sron Mor. Also the Central Electricity Authority had selected a 300 MW scheme at Ffestiniog in North Wales as a first beginning. In this scheme, reservoir capacity was to be provided to permit a generating period of up to 4 hours a day at maximum output, and pumping would take place during the night over a period of up to 7 hours. Each set would consist of three machines, namely a pump, a turbine, and an alternator/motor, arranged vertically. The changeover from pumping to generating and *vice versa* would be carried out by means of mechanical couplings, and would take 8 to 10 minutes per set. The cost of the scheme was estimated at about £12 million, or £40 per kW excluding transmission. Other schemes were now under consideration in England, totalling 750 MW, while in the North of Scotland further projects were under investigation.

The authors went on to discuss the economics of pumped-storage schemes when operating in conjunction with thermal plants. They showed that in favourable circumstances the capital expenditure on a pumped-storage project might be considerably less than the corresponding capital expenditure on equivalent thermal plant, and this was likely to be particularly true where such schemes were superimposed on projects which justified promotion as ordinary hydro-electric developments. It was also suggested in the paper that pumped-storage schemes were likely to be highly economical where circumstances permitted appreciable saving in capital cost per kW (including transmission) as compared with the corresponding cost of new thermal plants. The saving in capital cost due to the use of pumped-storage plant would be of special importance in times of capital shortage.

The authors then touched on the fact that two future sources of power would render the use of pumped storage increasingly desirable—the advent of high-temperature, high-pressure, large-scale steam generating units, and the development of nuclear power stations, both of which should be run at maximum load factor. The authors also stated that under suitable conditions a limited amount of pumping applied to natural hydro schemes would result in improved flexibility of operation, and thus result in an overall economic advantage.

The very large multi-purpose plant known as the Rhine-Main-Danube scheme was cited, in a paper by Ing. Steinhauser, of The Federal Republic of Germany, as a remarkable example of this type of development. The simultaneous development of the river for navigation and power generation is an example of maximum use being made of the natural resources of several rivers under several national authorities.

The example of the Tennessee Valley Authority has been followed by a number of other countries where multi-purpose developments are or are about to be instituted. The active participation of the State, local industrial interests, agricultural and navigational authorities and even of the entire population, were shown to be necessary to the success of these projects in a paper by Mr. Charles W. Kinney, of the Corps of Engineers of the U.S. Department of the Army.

Design of Turbines and Electrical Equipment

Kaplan turbines for a head of 208 ft. have now been developed, and a paper by Professor H. Gerber, of Zurich, describes these machines. He stated that at the present time there were no prospects of lowering the runaway speed of such machines without reducing the safety factor of the plant.

Extensive cavitation tests on Kaplan turbines have been carried out in Japan, and these were described in a paper by Mr. Takeda, of the Electric Machine Industry Association of that country. He maintained that Japanese manufacturers, in constructing new power stations and reconstructing old ones, had improved the efficiency of turbines to a remarkable extent, and he cited recent figures showing maximum efficiencies of 94 per cent. for Francis turbines, 93 per cent. for Kaplan turbines, and 91 per cent. for Pelton wheels. Although the raising of the specific speed limit as high as possible for a given effective head led to reduced weight and manufacturing costs, it resulted in a decreased efficiency, and caused erosion of the blades and cavitation phenomena. However, taking into account the results acquired from cavitation tests with model runners and from practical experience, it had become the general tendency in Japan for propeller or Kaplan turbines to be designed for higher specific speeds than those suggested by the National Electro-Technical Committees.

"Feathering" Francis Turbine

One of the most interesting developments in regard to hydraulic machinery, and perhaps the only totally new device mentioned at the Conference, was the "feathering Francis" turbine of the Deriaz design, as developed by the English Electric Company. This was described in the paper by Mr. Braikevitch, who stated that the studies undertaken to develop a movable-vane turbine for higher pressures indicated that in conventional axial-flow arrangement, the runner hub would become so large and the vane so narrow as to result in an appreciable loss in efficiency. Accordingly, a logical step was the adoption of a Francis runner with movable vanes. The axes of the vanes, instead of being at right angles to the turbine-shaft centreline, are inclined to it at an angle; and once this principle is adopted the hydraulic limitation of the conventional movable-vane turbine for high heads is overcome. While this machine was being developed in the English Electric Company's works at Rugby, the Hydro-Electric Power Commission of Ontario was studying the possibility of a pumped-storage scheme to ensure the most effective use, over a 24 hr. period, of the water available under Treaty Rights at their Sir Adam Beck station on the St. Lawrence. The proposed capacity of the reversible pump-turbine installation was of the order of 280,000 h.p., the head between the reservoir and the power canal being about 55 ft., rising to 90 ft. when the reservoir was full. The answer was provided by the Deriaz "feathering Francis" machine, which, when working as a pump, would discharge 5,040 cusecs. against a head of 59 ft., and 4,050 cusecs. against a head of 90 ft. When working a a turbine, the output would be 24,000 h.p. under a 60 ft. head, and 45,000 h.p. under a head of 83 ft. The running speed either when pumping or generating would be 92·3 r.p.m.

High-head reaction turbines for the Bersimis plant of the Quebec Hydro-electric Commission and for the T.1. plant of the Snowy Mountains Authority, were also described in Mr. Braikovitch's paper. The Bersimis machines had a maximum output of 175,000 h.p. under a head of 875 ft., while the Snowy Mountains machines gave an output of 134,500 h.p. with a maximum net head of 1,095 ft.

Asynchronous Generators for Small Plants

While the majority of the papers were naturally concerned with large-scale hydro-electric plants, there are throughout the world a vast number of small projects which are capable of making a useful contribution to local needs. Here, the use of asynchronous generators is particularly useful, while the compact bulb-type machines developed in France and Germany enable the utmost use to be made of the available water at a low capital cost. These aspects of hydro-electric practice were touched on in a paper by Professor Otto Henninger and Herr Christaller, of the Federal Republic of Germany. The tube- or bulb-type machine was also described in detail in a French paper by Mons. H. Chamayou. He described the Castet installation, where the available head is only 7·5 m., and two tube-type units of 1,100 h.p. each are installed. It was claimed that machines of this design have enabled the very necessary reductions and simplifications in engineering work to be achieved. These machines, thanks to their excellent cooling, had smaller dimensions than machines of the usual type, and the power-plant building, the main purpose of which in a conventional installation is to house the machines, could practically be done away with altogether. The saving made has amounted to over 40 per cent., and no supervision staff is needed. Machines of this type are to be used on the world's first tidal-power project, which will be the subject of a separate article in a future issue of WATER POWER.

Remote-control Equipment

On the electrical side, a greatly extended use of remote-control equipment is to be noted. An interesting example relates to the high-pressure storage plants in southern Germany, which are given the function of maintaining the frequency in an interconnected system. They are operated automatically, and equipped with remote control. The whole of the Schluchsee plant, of 524 MVA, is completely remote controlled. In the paper by Professor Henninger and Herr Christaller it was stated that the use of tele-metering devices over distances of up to 373 miles had proved to be perfectly satisfactory, the remote-control equipment operating within a few seconds to change the plant from pumping to generating in the case of the pumped-storage installation, while all the other control functions, including phase shifting, were also carried out in this way.

Another example of complete automatic control of starting and stopping a turbine, phase shifting, pump operation and hydraulic short-circuit operation, were given in a paper from Austria. This described the Tauern plant which has a maximum capacity of 83,000 h.p. Some 230 relays were required for the automatic equipment controlling this station.

In the discussions on the first hydro-electric session, Professor Dr. Thirring, of Austria, pointed out that on the frontier between India, Pakistan and China there existed an opportunity for the erection of the largest hydro-electric station in the world. By cutting short a river bend through the medium of a tunnel 50 km. long, a head of more than 2,000 m. could be obtained. With the very large flow available, a production of 150 to 300 billion kWh could be obtained. Mr. Huang Yu-Hsien, of China, said that Chinese engineers had already started on detailed studies of

the potential water power mentioned by Professor Thirring.

In the remainder of the discussion various engineers amplified their papers by additional slides, and in some cases films, but no particularly new features emerged. Professor Kopetzky, of Czechoslovakia, described research work on a Kaplan turbine for a head of 71 m., and a flow of 150 cu. m. per sec.

Construction and Operation of Hydro-Electric Plants

The second section of the hydro-electric sessions dealt with the construction and operation of hydro-electric plants, and again Dr. Grzywienski provided a comprehensive general report of considerable value. Since the last World Power Conference there has been notable progress in concrete technology, cofferdams and rock-excavating techniques. In concrete technology this progress relates to the increased use of prefabricated sections for dams and other hydraulic structures. An Austrian paper may be taken as typical of this type of technique. Ing. Wilhelm Steinböck described the construction of the Grosser Mühldorfer See plant, which the upstream and downstream sides of the dam, 40 m. high, are faced with prefabricated vacuum-concrete slabs, placed in position by a derrick. A very considerable saving in shuttering has been achieved in this way, and the time taken for the construction of any particular section of the project has been found to be considerably shortened compared with other methods.

Much research has taken place in regard to fine-grain technology in concrete mixing, and a typical paper setting out the latest practice was given by Ing. Scholtis and Dr. Fritsch, of Austria. They described the concrete-mixing plant employed on the Ybbs-Persenbeug plant, which has been the subject of a recent article in WATER POWER.*

Prepakt Concrete

The use of "prepakt" concrete for saving time in the construction of pressure shafts was described in an interesting paper by Mr. F. L. Lawton, of Canada, who gave an account of the well-known Kemano project. He said that the utilisation of "prepakt" concrete for backfilling the space between the steel liner of the 11 ft. diameter conduit and the rock envelope was believed to be the first instance of the use of this technique on an extensive scale. It proved possible to place aggregate at an average rate of 3 ft. length of conduit, sloping at an angle of 48°, per hour. After experience of this method had been improved, the lower leg could be completed in a single lift of 1,940 ft. Grout in the "prepakt" aggregate backfill in the lower leg was placed at an average rate of 4 ft. per hour. Laboratory investigations and numerous test cores showed no unfilled voids in the aggregate, or other unsatisfactory conditions.

A number of papers dealt with automatic operation and showed that the efficiency of a given station could often be improved by automatic equipment. Semi-automatic operations with one-man remote-control equipment was described in a Japanese paper by Mr. Sadao Saeki. He stated that this system, operating from the main switchboard of the power station, did not only cover the whole of the requirements of the generating units themselves, but also the operation of the intake gates at the dam. If needed, various essential parts of the equipment could be operated by standby diesel generators. Some of the Japanese power plants were equipped with television sets for checking the water level near the intake gates of the dam. A number of the smaller power plants were arranged for self-starting.

Dr. Grzywienski ended his General Report by referring to the steady progress made in the development of large cableway equipment and excavating machinery, and to the change-over from track-mounted transport to trackless types. Concrete production was gradually becoming completely automatic, and belt-conveyor transportation, both of aggregate and fresh concrete, was increasingly used.

Increasing Size of Installation

The General Reporter summed up the position in regard to the increasing size of hydro-electric equipment. This increase in dimensions also extended to dams: the highest gravity dam at Grande Dixence, would have a height of 935 ft., while the Mauvoisin arch dam had a height of 777 ft. At the present time the highest horsepower capacities in operation were given as follows:—

Kaplan Turbines: 111,000 h.p. at McNary dam, U.S.A.
Francis Turbines: 165,000 h.p. at Grand Coulee dam, U.S.A.
Pelton Wheels (one jet): 150,000 h.p. at Cimego, Italy.
Pelton Wheels (four jets): 150,000 h.p. at Kitimat, Canada.
Storage pumps: 102,000 h.p. at Hiwassee, U.S.A.

The capacity of waterwheel generators had already reached 150,000 kVA at Stornorrfors, in Sweden.* The largest capacities of a single installation stand, in regard to plants recently completed or still under construction, as follows:—

McNary Dam — 1 million kW
Kuibischeff (USSR) — 2·1 million kW
Kemano (turbine capacity) — 2·4 million h.p.
Bersimis plant — 1·2 million h.p.

The General Reporter summarised the world's total utilised and potential water power in the accompanying table, but it must be realised that at the time this was prepared Dr. Grzywienski would not have had the opportunity of seeing the Russian and Chinese papers, produced only at the very beginning of the Conference.

Continents	Utilised Water Power in million h.p.	Potential Water Power in million h.p.
Europe	48·5	64
North America ...	46·4	90
Asia	14·4	156
South America ...	3·9	62
Australia and Oceania	1·8	23
Africa	0·7	250
Total	115·7	645
Total without Africa	115·0	395

* "The Ybbs-Persenbeug Plant." By Dr. E. Königshofer. WATER POWER, June 1956, p. 207.

* The largest waterwheel alternators under construction in the world are claimed to be the 138,000 kW machines for Bersimis.—EDITOR, WATER POWER.

The only basically new ideas in hydro-electric development found in the papers by the General Reporter were the bulb-type generators for use with low-head schemes, the development of reversible pump turbines and the utilisation of tidal power for the first time.

Co-ordination the Key to the Future

In general, the papers and Dr. Grzywienski's admirable General Reports indicated that there is no diminution of interest in water-power development as a result of the impending production of nuclear power. There is, however, a trend towards the co-ordination of hydro-electric plants with other types of plant, and here a quotation from the General Report may be of interest: "Hydro-electric power will, in the future, be considered less and less as an independent factor. We shall have to count upon the percentage share of water power towards the total power production no longer as being increased in certain countries, such as Great Britain, the USA, USSR, Belgium and others, through the coming development of atomic power; and this will be caused partly by the shortage of potential water power in these countries and partly by other reasons, such as the availability of raw materials for nulcear energy. Co-ordination, therefore, will be the main characteristics of the future—the connecting of large systems, uniting the various kinds of power, such as atomic power, thermal power, water power (including inland, tidal and ocean power) and to a certain extent wind power . . . Water-power plants will also have to compete more keenly from an economic standpoint with the other types of power in the future.

"The limits of water-power development have already made themselves clearly discernible in a few countries, such as Italy, Sweden and Switzerland, but . . . water-power utilisation will continue to develop for the next few decades. The steady and rapid rise in power demand calls for the speedy development of water-power, since other kinds of energy are not yet available at the same price. Where other purposes can at the same time be fulfilled by hydro-electric power production, the latter may be considered superior in any case.

"It is conceivable that there will be an increase in hydro-electric development in those places where nature still has more to offer, for example, India, the United States, Brazil and Africa. Aims for the future should be greater utilisation of large rivers, lakes and oceans: greater versatility of structures and machines; development of the construction of dual-purpose machines, consisting of pumps and motor or turbine and generator; and complete automatic control."

Points from the Discussions

In the discussions, Mr. Azzemuddin, of Pakistan, stressed the very great importance of hydraulic engineering structures in the "so-called undeveloped countries." In the deltas of the largest rivers, such as the Brahmaputra, the Ganges and the Megna, floods repeatedly caused great damage. Multi-purpose plants would enable these rivers to be regulated and so prevent catastrophic floods. Mons. Gibrat, of France, emphasised the need to supplement thermal and nuclear power plants with pumped-storage equipment.

The operation of a chain of run-of-river plants was mentioned by Mr. Sebaher, of Yugoslavia, who said that there should be a greater exchange of experience on the overhaul and maintenance work on interconnected plants. Work of this nature on one machine could affect the operation of the whole chain.

Mr. Mechinkov, of the USSR (Director of the Institute for the Design of Water Power Stations), surveyed Russian plans for the near future, and said that standardisation considerably facilitated design work. Continuously operating concrete plants were found to be of great assistance in speeding up the work, and emphasis was being placed on methods for ensuring uninterrupted construction even during the winter months. New types of shuttering, such as prefabricated concrete plates or narrow-meshed wire nets, were being employed. Assembly yards, which would permit the assembly of elements of up to a weight of 1,000 tons were being developed, thus shortening construction time.

Another Russian engineer, Mr. Tchernyshov, spoke of developments in turbine construction. The welding of large turbine parts had resulted in a considerable saving of weight. Theoretical research in the Soviet Union was concerned with the increase in speed for large generating units, and the prevention of cavitation. On the constructional side, he said, special machine tools had been developed to allow for rapid simultaneous machining of turbine blades on both sides.

Swedish delegates spoke about the great improvements in rock tunnelling which had taken place in that country; and other delegates spoke of peak accomplishments in concrete placing, for example, at the rate of 20,000 cu. m. in a single day.

Conclusion

In conclusion, we can do no better than to quote the final paragraphs of the General Report. They run: "Engineers are faced with enormous tasks of a qualitative nature, and with dimensions never before visualised. On the other hand, however, technical and economic aids have been increasing from day to day, and support us in our efforts to solve these problems.

"From the local problems and their local solution of yesterday have developed the great problems of world-wide importance which can only be solved through united efforts. This is proved by the attempts at international co-ordination in the field of hydraulic economy. It leads to an exchange of material and ideas so that the progress achieved in one country very quickly spreads over the whole world . . . Hydraulic economy does not only change the face of whole continents through its gigantic projects, but also shows the trend towards world-wide uniformity through the rapid exchange of information and quick extension of improvements and innovations.

"We do not doubt that this circumstance in particular will contribute considerably to the mastering of the enormous problem of the full exploitation of water in every form, even in the coming atomic era, to the benefit of the individual and mankind in general."

Conference on Power from the Sea. In our next issue we shall commence our review of the Conference on Power from the Sea, which was held in Paris just before the World Power Conference.

Fig. 11. General view of the north machine hall, Aura power station

The Aura Development

Aura power station has a capacity of about 300 MW and is the largest single power plant in Norway. It also contains Norway's largest generating sets. The power is being used partly to supply an aluminium works at Sunndalsora, partly for local supply, and partly for bulk supply to the surrounding districts

PART TWO

A PLAN of the station showing the disposition of the north and south machine halls is given in Fig. 12. The machine halls lie about 300 m. into the mountain and are 50 m. apart. The two penstock tunnels come down on the outside of their respective halls, and the south hall, which houses the larger machines, is served by a separate valve chamber. Both halls discharge to a common tailrace tunnel, 29 sq. m. in cross section and 575 m. long, whence a canal 190 m. long leads into Sunndalsfjord.

For the north hall the excavation required was 18 m. wide, 17 m. high and 123 m. long, of which the machine hall itself occupies a length of 83 m. For the south hall the corresponding figures are 17 m. wide, 15·3 m. high and 95 m. long, of which the machine hall occupies 68 m. As will be seen from the plan, a switchgear chamber is located at the end of each hall towards the entrance, and in the case of the north hall this is succeeded by a transformer chamber.

Cross-sectional elevations of the two halls are given

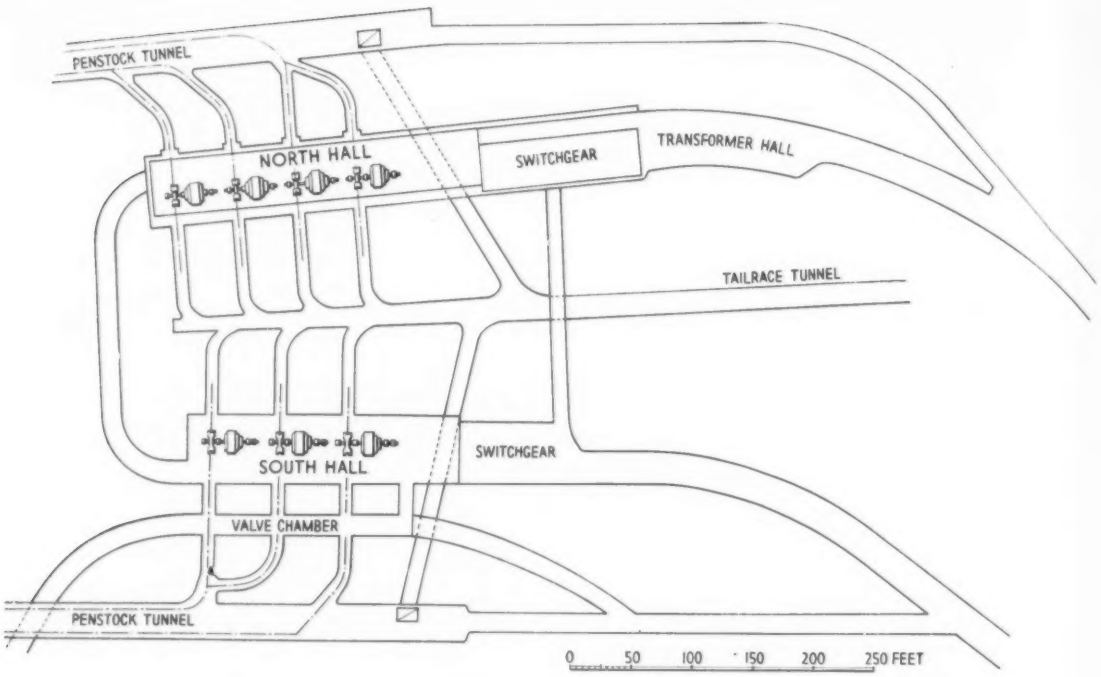

Fig. 12. Plan of Aura power station showing the disposition of the north and south machine halls

in Figs. 13 and 14, from which it will be seen that each hall has a reinforced-concrete false roof, above which a space has been left to arrest any falling stones and to divert seepage water. Further, in order to reduce the reflection of noise, the roofs have not been arched but have three flat faces.

As it was not possible to predict with certainty the behaviour of the rock during excavation, the procedure in cutting out the north hall, which was the first to be constructed, was somewhat experimental, and the concrete roof was inserted as the excavation proceeded. When the south hall came to be cut out it was found possible to complete the excavation and support it with roofbolts before the concrete roof was constructed. This led to a saving in concreting costs because concrete transport was easier, and it was possible to place the concrete by pumping.

In the north hall the roof consists of a 30 cm. membrane carried on trusses 1 m. deep at 4 m. centres. Tie rods of reinforced concrete also connect the trusses with the rock above. After a time it was noticed that some of the rods had been strained to breaking point by the settling of the overlying rock, and also that the seepage water contained an abnormal percentage of sulphur, which was corroding the concrete of the tie rods and causing swelling. An asphalt compound was therefore applied to protect the tie rods. In the south-hall roof the tie rods were omitted.

Ventilation is separate for the two halls, the fans being placed in the chambers containing the switchgear and other apparatus. In each case fresh air is drawn in through the cable gangway, distributed between the walls and the rock to the machine hall and other rooms, and exhausted through the access tunnel. The total fan capacity is 230,000 cu. m. per hour.

Turbines

The turbines for the four generating sets in the north hall were built by Escher Wyss Abt., Switzerland, and were originally designed for a head of 840 m. for a station at Osa, but were detained at Bremen during the war. When they were released it was decided to utilise them for the Aura development, and they were overhauled and fitted with new nozzles, although the wheel pitch-circle diameter of 2,260 mm. is somewhat smaller than would have been chosen if the machines had been designed for the Aura conditions. As modified, the turbines were expected to develop 35,000 to 39,800 h.p. at 500 r.p.m. under a head of 720 to 790 m., the discharge at full load ranging from 4·12 to 4·32 cu. m. per sec. However, the actual output has proved to be considerably higher, being up to about 49,000 h.p.

Two of the turbines in course of erection in the makers' works are depicted in Fig. 16. They are of the single-wheel two-jet type, the wheel having 24 bolted-on stainless-steel buckets. The jets have a diameter of 159 mm. and strike the pitch circle tangentially at an angle of 75 deg. to each other. Each generating unit forms a three-bearing assembly, one bearing, which includes the thrust collar, being incorporated in the turbine.

The turbine casing consists of a cast-steel front plate and four cast-iron sections, the back plate and the lower nozzle being protected by cast-steel shields. Pressure springs in the connection between the nozzle lead-in pipes and the front plate relieve the casing of stresses due to movement of the nozzle assemblies under the influence of temperature changes or water pressure. The pit liner, which is bolted to the lower edge of the casing, carries an erection grid and is pro-

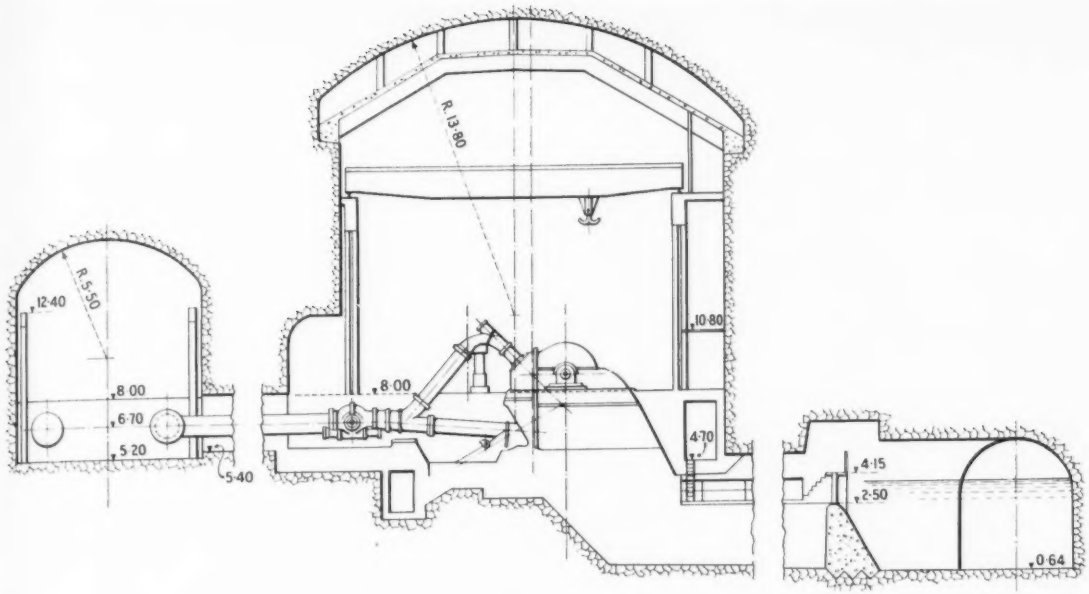

Fig. 13. Section through north machine hall

vided with an inspection door and a ventilation opening.

In each turbine the spears of both nozzles are controlled by a common servomotor, and a common servomotor is also used for the deflectors. Both servomotors are impelled towards the closed position by water under penstock pressure, this pressure being resisted by oil pressure acting on the opposite side of the piston under governor control. Thus, in the event of a failure of the governor oil supply, the turbine will automatically shut down. A like result is secured by the operation of the overspeed trip on the turbine shaft, which releases the oil in the servomotor cylinders.

The oil supply for each turbine is derived from a tank sunk into the floor, whence it is withdrawn by two sets of pumps, each set consisting of a governor-oil pump supplying the usual air chamber, and a lubricating-oil pump. The pumping set normally in use is driven by an a.c. motor, and the reserve set by an auxiliary turbine which comes into action automatically in the event of a current failure.

In advance of two of the turbines is an Escher Wyss 850 mm. bore spherical valve in the machine-hall

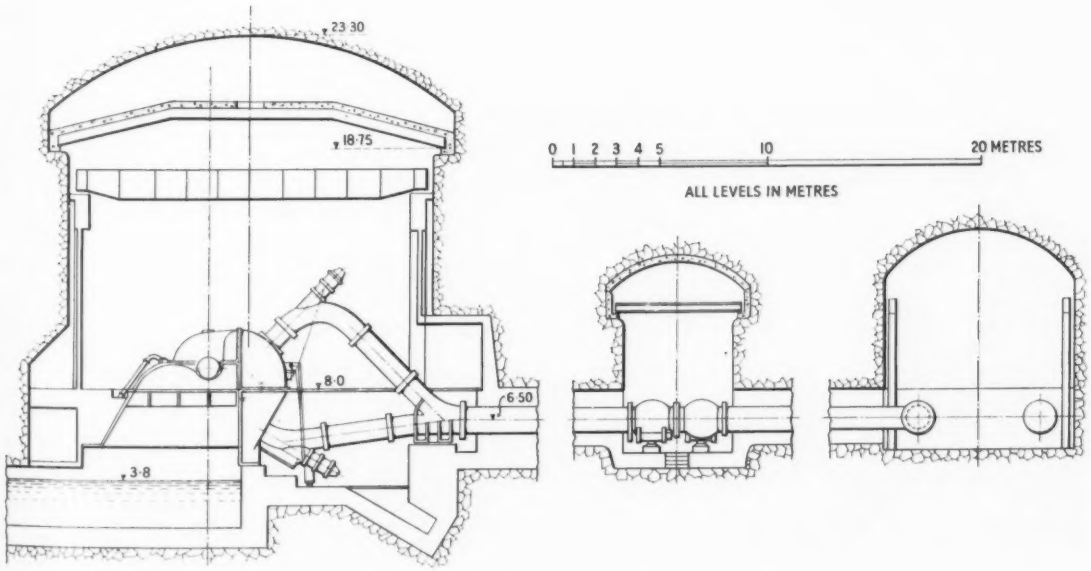

Fig. 14. Section through south machine hall

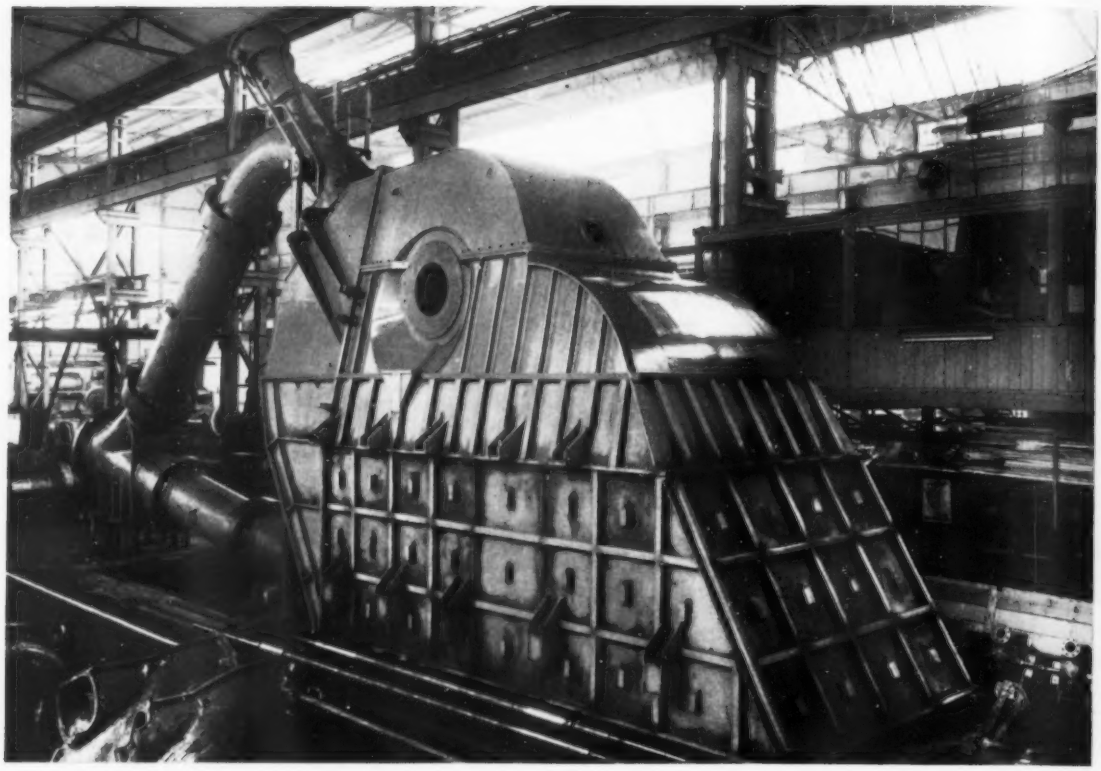

Fig. 15. Casing of one of the 78,600 h.p. 428 r.p.m. Escher Wyss turbines for the south machine hall

basement. These valves are actuated by pilot control valves which are electrically operated from control desks close to the governor units of the respective turbines.

In the case of the south machine hall, as already stated, the valves are in a separate chamber, and furthermore the valve system differs from that obtaining in the north station. Nos. 1 and 2 turbines, which are supplied from penstock C, each have two spherical valves fitted in sequence, the downstream one being used for normal operation and the upstream one to enable the unit to be shut off for repairs without emptying the penstock and incapacitating the other machine. No. 3 turbine, which is the only machine fed by penstock D, has only one valve because in the event of a shutdown for repairs there is no objection to emptying the penstock.

The valves and turbines for the south machine hall were all constructed in the Escher Wyss works at Ravensburg, Germany. The turbines, which are the most powerful in Norway, and amongst the most powerful horizontal single-wheel units in Europe, each develop 78,600 h.p. at 428 r.p.m. under a head of 740 m., the corresponding discharge being 9 cu. m. per sec. Like the north-hall turbines, they are two-jet single-wheel machines, the jet diameter in this case being 230 mm. One of the machines is seen under construction in the works in Fig. 15.

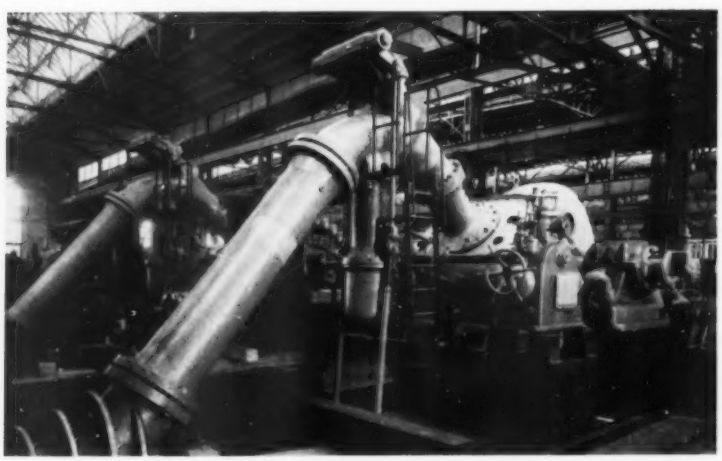

Fig. 16. Two of the 49,000 h.p. (actual) Escher Wyss turbines installed in the north machine hall

The three-bearing arrangement of the north-hall generating sets obtains also for the larger south-hall units, but in other respects there are some important differences. The casing is welded throughout, and in the region of the lower nozzle the front plate is made sufficiently elastic to accept any thermal expansion or contrac-

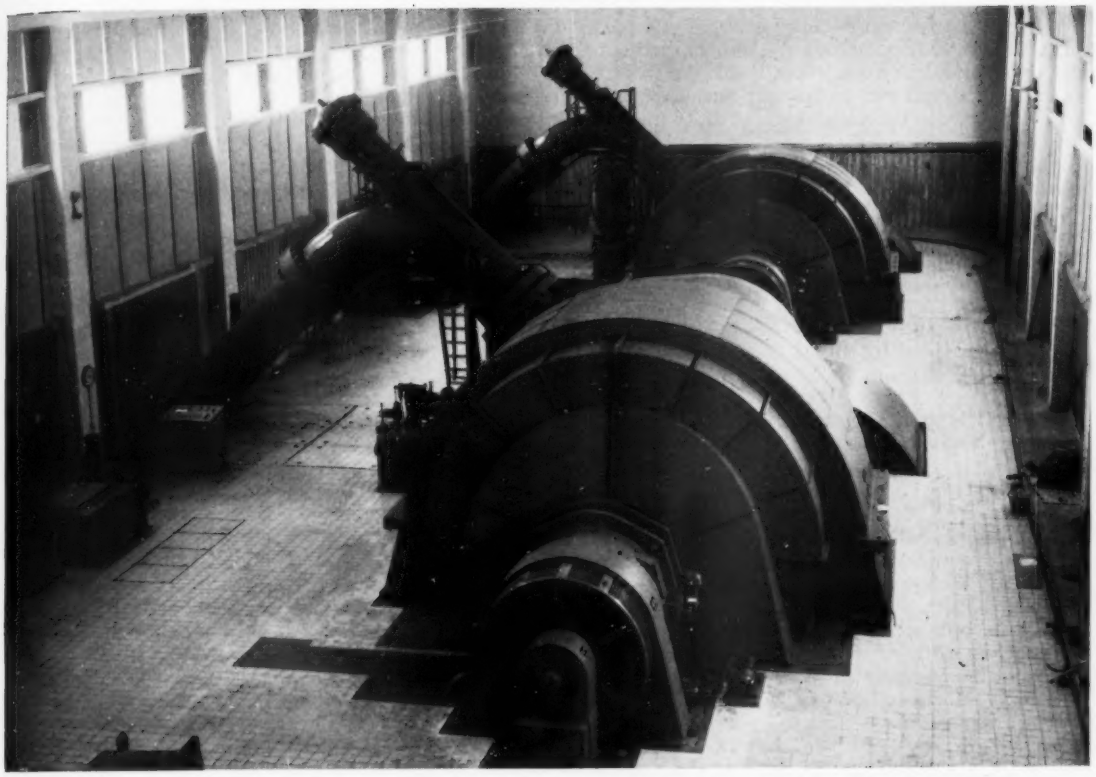

Fig. 17. South machine hall showing the sets equipped with Metropolitan-Vickers 62·5 MVA generators

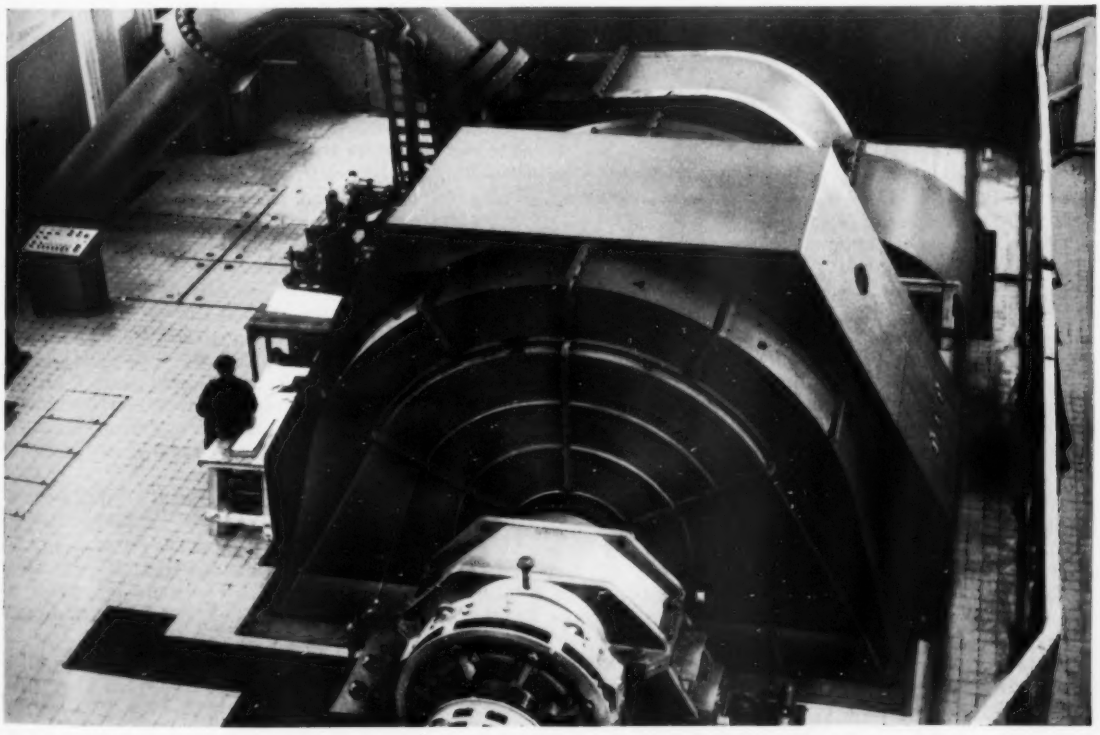

Fig. 18. G.E.C. 62·5 MVA generator in the south machine hall

tion or water-pressure movement of the lead-in pipe, which is comparatively straight. In the region of the upper nozzle, on the other hand, the front plate is deliberately stiffened so that any movement is taken up by the bend in the lead-in pipe itself. In the pit liner are a door and a light inspection footbridge, and covered recesses are provided to carry an erection platform.

The wheel has a pitch circle of 2,500 mm. and is a solid manganese-steel casting incorporating 21 buckets. For each turbine a spare wheel has been provided, cast in stainless steel.

Unlike the north-hall machines, each nozzle has its own spear servomotor, although a common servomotor is provided for the deflectors. The system of actuating the servomotors by a controlled oil pressure against water at penstock pressure is again employed, and the oil-supply, governing and control arrangements are similar to those in the north hall.

Generators

All four 37·5 MVA generators and two of the three 62·5 MVA generators were supplied by Metropolitan-Vickers Electrical Co. Ltd., Manchester, England. They are salient-pole machines with the stator yokes fabricated from steel plate, and for convenience of transport and erection the stators are split horizontally. Stator windings are of the involute or basket type split horizontally for shipment and arranged for the joints to be made on site.

The rotor bodies are built up from forged steel discs, spigoted together and fitted with through-bolts with the shaft ends bolted to the ends of the rotor body. Dovetailed slots, two per pole, are machined in the rotor body to receive the poles which are built up from laminations and wound with copper strap coils, and are keyed into position.

Ventilation is on the closed-circuit system with the ventilating air passing over water-tube coolers mounted below the machines. Air is forced round the machine and over the coolers by fans on the ends of the rotor body.

Lubrication for the 62·5 MVA machines is forced oil, but the 37·5 MVA machines have water-cooling tubes embedded in the bearings.

Each machine has a main exciter and a field exciter, the armature of the latter being overhung from the main exciter shaft.

A view of the 62·5 MVA Metropolitan-Vickers machines is given in Fig. 17.

The remaining 62·5 MVA generator was built by The General Electric Co. Ltd., Birmingham, England. The complete alternator weighs 310 tons, of which the rotor alone accounts for 170 tons. For reasons of transport it has been designed so that it can be shipped in sections, none of which weighs more than 55 tons. A view of this machine, installed in the south hall, appears in Fig. 16.

Electrical System

The output from both machine halls is controlled from a common control room, seen under construction in Fig. 20. Reference to the main electrical circuit diagram, Fig. 19, will show that the control scheme is necessarily somewhat complicated by reason of the fact that supplies are sent out at no less than three voltages, in addition to low voltage for station auxiliaries; nevertheless a study of this diagram will reveal the extreme flexibility of control that has been secured.

All power is generated at 12 kV, and the aluminium works are fed at generator voltage. Supplies for the immediate district are sent out at 22 kV, and the bulk supply to Møre og Romsdal and to Trøndelag is transmitted at 132 kV. Station auxiliaries are supplied at 230 V.

Duplicate busbars are used throughout, and the north and south halls are connected to sectionalised bars so that they can operate in parallel or independently. Incidentally, a water load is placed between the sections to enable any machine in either hall to be tested. Furthermore, isolators are provided so that each machine can not only be coupled to either busbar but alternatively can be connected direct to a corresponding feeder in the case of the south hall, or a transformer in the case of the north hall.

Normally the two halls operate independently, the south hall supplying the aluminium works and the north hall providing the public supply. From the south hall three feeders are taken to the aluminium works, supplied either from the busbars or from their respective machines, but supplies can also be obtained from the north hall, either through the sectionalised busbars and thence through feeders 1-3, through a fourth and fifth feeder from machines Nos. 4 and 5, or from a sixth feeder supplied from the north-hall busbars. During the construction period units Nos. 4 and 5 were the first to be placed in service, and the aluminium works were supplied from feeders Nos. 4 and 5 until units Nos. 1 and 2 in the south hall commenced to generate.

Turning now to the public supplies, power is fed from the north hall to the 132 kV system through four 37·5 MVA 12/139·2 kV star-delta transformers, each placed electrically opposite to its corresponding generator, the transformer neutrals being earthed through a Petersen coil. Thence the power is passed to an outdoor double-busbar substation from which overhead lines are taken to Istad and Trøndelag. Provision has been made for these lines to be duplicated and for two lines to be constructed to Osbu and Mardøla. From Osbu a future connection with the south-eastern Norwegian grid may be made.

For district and station-auxiliary supplies power is transferred to a separate set of 12 kV duplicate busbars, with supply from any unit as desired. From these bars two transformers, one of 8 MVA and the other of 5 MVA capacity (the latter to be replaced later by an 8 MVA unit), feed a further pair of duplicate busbars at 22 kV, whence district supplies are taken off to Sunndalsøra and Øksendal, an interconnection is made with the construction station, Dalen III, and a feeder is taken up to the valve chambers at the top of the penstock tunnels.

The auxiliary supply for the north machine hall is also taken from these 12 kV bars through two 750 kVA transformers feeding duplicate bars at 230 V. For the south hall, the arrangement of step-down transformers and low-voltage busbars is similar to that obtaining for the north hall, but the transformers are supplied from a single set of sectionalised busbars fed either from the south-hall main busbars or direct from one of the three machines.

All the control equipment has been supplied by EGA, Oslo, the voltage regulators and part of the protective gear being of ASEA manufacture. The 12

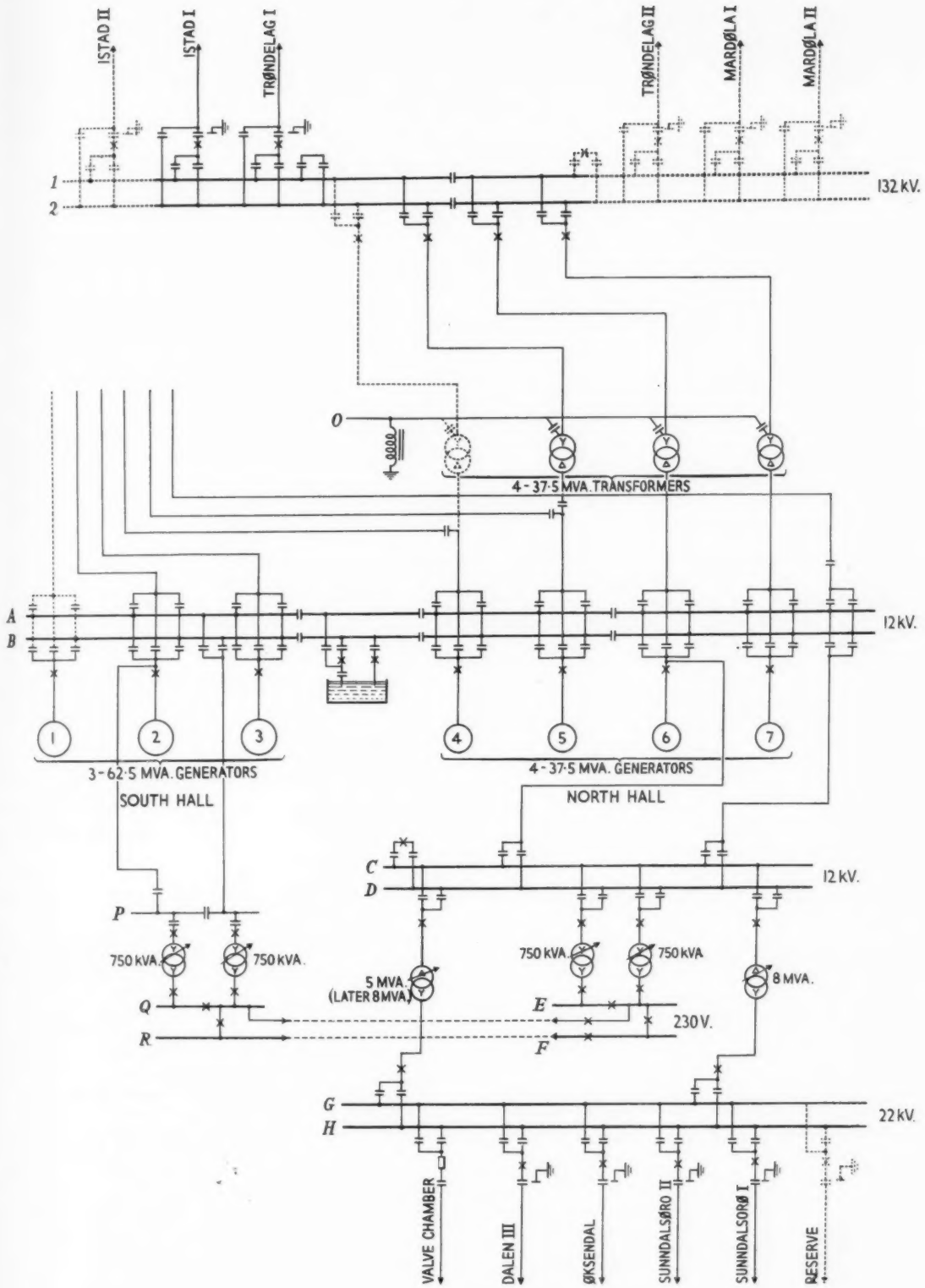

Fig. 19. Electrical system of the Aura development

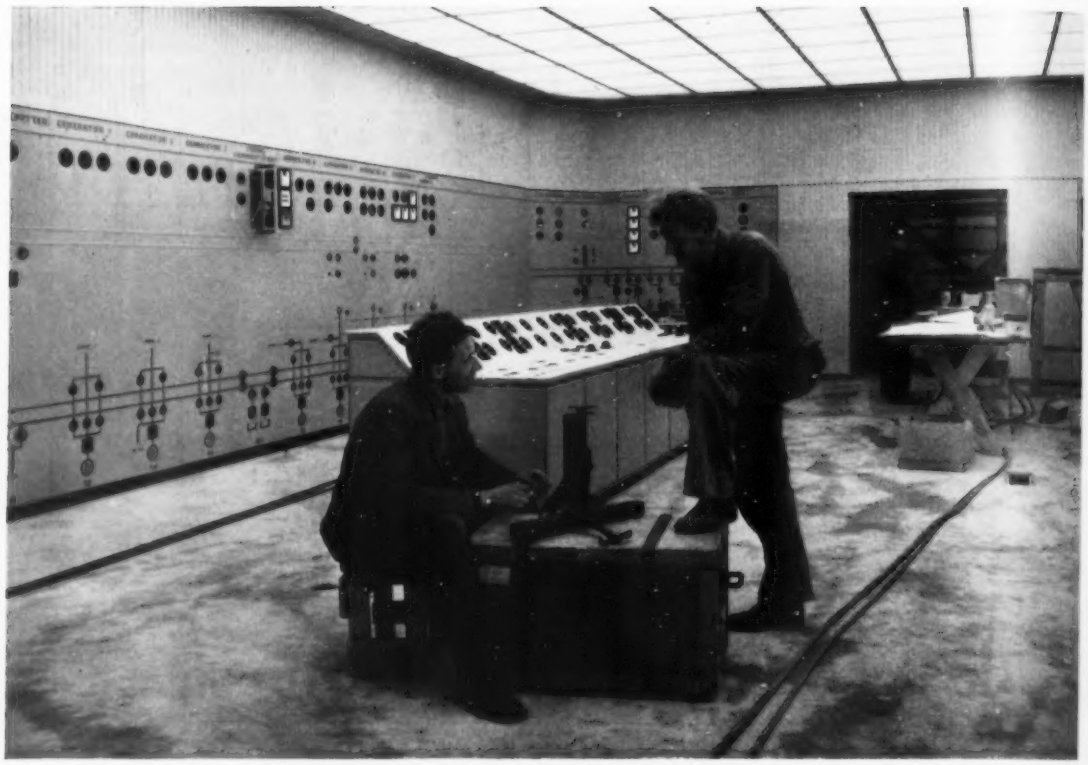

Fig. 20. The control room in course of being equipped

kV switchgear, which is of 1,500 MVA rupturing capacity, is of the air-blast type and is housed in the switchgear annexes at the ends of the machine halls. It was built by EGA, Oslo, under Westinghouse licence.

All transformers were built by A.S. National Industri, Norway, the main step-up transformers and the Petersen coil (by Savoisienne, Aix les Bains) being placed in the transformer chamber between the north hall and its access tunnel. Automatic tap changers are fitted to the 132 kV and 22 kV transformers. All cables were supplied by Standard Telephones & Cables Limited, Oslo, those at 132 kV being oil filled. A longitudinal partition in each access tunnel forms a cable gangway through which the cables extend to the tunnel portals. Here they terminate in outdoor insulators carried on a fabricated structure, whence all power is carried by overhead lines. The 132 kV substation is controlled by Delle minimum-oil outdoor-type circuit breakers of 1,500 MVA rupturing capacity.

A Comment on Design

The unusual character of many of the features in the design of the Aura power station will not have been lost on the reader, but as may have been gathered, the final design was very much influenced by the use of equipment and machinery available after the war on German contracts for other plants in Norway. Furthermore, the step-by-step decisions—first limitation to a comparatively small installation for general power consumption, and later extension for delivery to the aluminium factory with extra demand on spare unit capacity—introduced complications. These facts explain the somewhat extraordinary arrangement of two halls with different sizes of unit and three outgoing voltages. On the other hand, as we have pointed out, the result is a very elastic arrangement, which makes it possible to adapt operation according to different kinds of demand.

Acknowledgments

We are happy to acknowledge our great indebtedness to Mr. Fredrik Vogt, Director of Norges Vassdrags-og Elektrisitetsvesen, and Mr. P. Broch Due, head of the Construction Department of the Board, for their permission to visit the Aura scheme and to publish this article, and also for their kindness in affording us the time for discussions on the Aura development and on Norwegian water power in general. We would also express our appreciation of the valuable assistance given to us by Mr. S. L. Hansen, the Board's Chief Mechanical Engineer, and by his staff both at headquarters and on site. We are also deeply grateful for the many services rendered to us by Mr. Ragnar Heggstad, Chief Engineer of Kraftforsyningens Sivilforsvarsnemnd, Oslo, and by Mr. H. S. Jacobson, former managing director of A/S Atlas Diesel, Oslo for their many good offices in connection with our visit. Much useful technical information has been derived from an article on the Aura development in "Norske Kraftverker," the centenary volume produced by *Teknisk Ukeblad*, the Journal of the Norwegian Society of Civil Engineers, which we reviewed in our September 1954 issue.

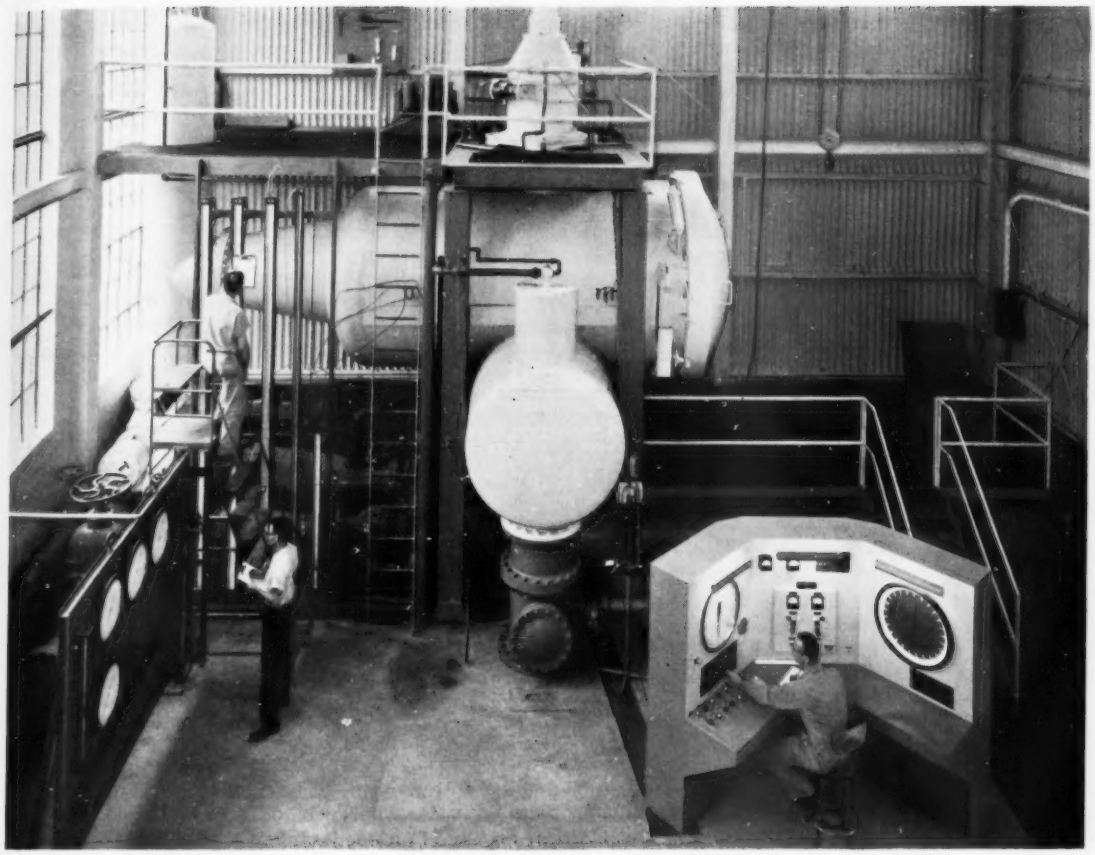

Fig. 1. A view of the new high-head turbine testing circuit

Morgan Smith High-Head Turbine Test Circuit

AN important addition has been made to the laboratory facilities of the S. Morgan Smith Company, York, Pennsylvania, by the commissioning of a high-head water-turbine test circuit which will be used for cavitation and other basic research and for formal contract acceptance tests with particular emphasis on the duplication of field conditions.

This is the fifth turbine testing circuit to be installed in the S. Morgan Smith hydraulics laboratory. The original equipment is a low-head open-flume circuit capable of testing models with a discharge diameter of 16 in. at a head of 10 ft. The second, installed in 1941, is a low-head pressurised circuit testing 12 in. models at heads up to 50 ft., and has been used almost exclusively for basic research and for the development of Kaplan and propeller turbines. Thirdly a pump-turbine test circuit was placed in service in 1945, accommodating models with eye diameters up to 12 in. and heads up to 85 ft. on the generating cycle, followed by a horizontal impulse test circuit in 1947, accepting models with runner pitch diameters from 22 to 46 in.

These circuits have now been supplemented by the new high-head test stand, which can test 12 in. models at heads up to 300 ft., and has been designed to be capable of producing the low sigma values necessary for many cavitation investigations.

To determine the minimum allowable or critical sigma in the laboratory, the model is usually tested with a constant wicket-gate opening (and blade angle in the case of a Kaplan turbine) at a constant speed under a constant head while the elevations of headwater and tailwater are lowered step by step for successive runs until a definite break or change in performance is observed. Considerable difficulty has usually been experienced in obtaining definite cavitation break-off points by plotting either efficiency, power or discharge against sigma values. Consequently, in many laboratories the chief means of studying cavitation inception has been by visual methods utilising stroboscopes and other visual aids. Recognising these early laboratory difficulties and limitations as well as the necessity of obtaining reliable numerical results in order to develop runners to meet modern requirements of higher speeds, smaller diameters and reasonable settings for any given head, it was decided that the primary function of this equipment was to obtain accurate and reliable quantitative

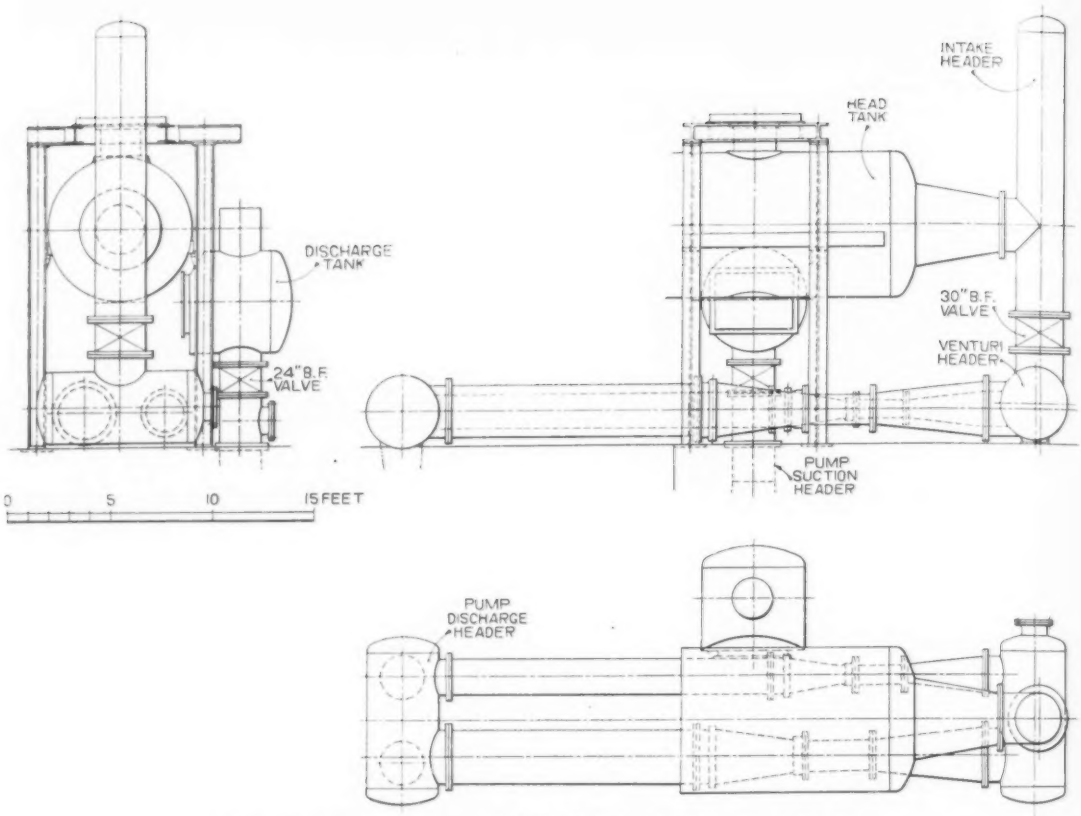

Fig. 2. General arrangement of the high-head turbine test circuit

results, and provisions for visual testing received only minor consideration since this work can be conducted in the low-head test stand. The new stand was designed entirely by the engineering staff of the company.

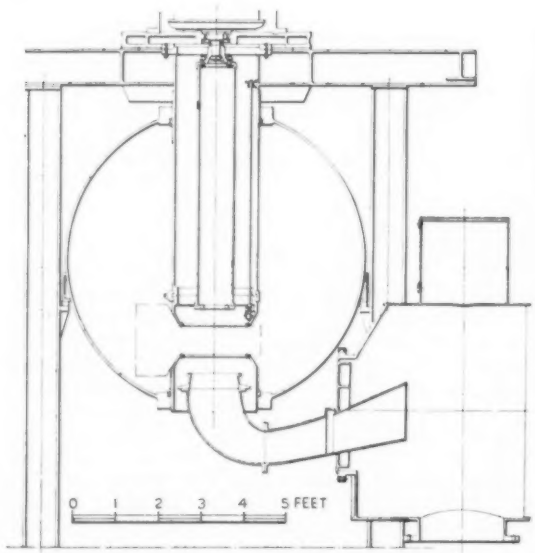

Fig. 3. Layout of the head tank

Referring to Fig. 2 the pumps discharge water into a discharge header and then through either of the venturi meters to the venturi header. It was originally felt that the intake header would require 5 ft. of air cushion to smooth out operation, but this has been found unnecessary; therefore, the header is used as a collector from which the air is allowed to escape when starting the test stand. The water flows from the intake header to the head tank and then through the turbine to the discharge tank. An air cushion is provided on the top of the discharge tank, and by adding compressed air, water under pressure or by evacuating air by means of a vacuum pump, the discharge pressure may be altered, thereby changing sigma during the tests. Numerous valves are provided for varying the test head on the unit. Fig. 3 shows a section through the head tank and the location of the wheel case. The head tank is large enough to accommodate a wheel case, scroll and some penstock if necessary.

The repeatable accuracy of this stand is considered to be plus or minus one-quarter of a per cent. The absolute accuracy considering the accurate calibration is within one per cent.

One 300 h.p., 0 to 6,000 r.p.m. eddy-current dynamometer is used to measure the turbine horsepower. The load is applied at a 21 in. radius to a calibrated Emery cell and reads directly in pounds load on the gauge board. The load-cell calibration is checked periodically with a Morehouse proving ring previously calibrated by the U.S. Bureau of Standards. The speed is measured by a mechanical tachometer.

pulley driven from the shaft, and an electronic speed counter using a magnetic pick-up and 60-tooth sprocket on the main shaft. The dynamometer also measures the down thrust on an Emery cell by hanging all the rotating components on the cell.

Two venturi meters are provided, one 30 in. × 16½ in. and the other 20 in. × 10 in., which were calibrated at Worcester Polytechnic Institute and the University of Pennsylvania respectively. The meter selected for measuring the flow is determined by the magnitude of the manometer deflections. Roto-valves are provided for shut-off service at the throats so that either venturi meter may be used. Several manometers are available for reading the meter deflections, including differential mercury, inclined mercury and water.

Each of the two pumps circulating the water is rated 9,500 g.p.m. under 118 ft. head with a guaranteed efficiency of 86.5 per cent. Each 300 h.p. pump motor runs at 885 r.p.m. These pumps are arranged to operate in series or in parallel so that under a head of 300 ft., 5,000 g.p.m. can be obtained from two pumps in series, and under a head of 100 ft., 21,000 g.p.m. can be obtained from two pumps in parallel.

Differential mercury manometers are used to measure the net head across the turbine below 150 ft. Heise gauges are used to measure the inlet-head pressure when the 150 ft. differential is exceeded. A mercury U-tube manometer is used for measuring the discharge tank pressure.

A 7 ft. diameter head tank is provided in which the wheel case is mounted. The elbow draft tube discharges through the bottom of this tank into the 5 ft. diameter discharging tank.

A 100 ton water-cooling system is used to maintain the 10,000 gallon stand capacity at a constant temperature. The water to be cooled is taken from the pressure side of the pumps and returned to the suction side.

A few outstanding design and operational features are noteworthy. At first, a stand capable of developing 80 ft. head for 12 in. discharge diameter models was deemed satisfactory, and rather extensive layouts were made for this design. However, upon studying the possibility of building a 300 ft. stand for the same-size models, this scheme was adopted for the following reasons:

1 The added expense of building a 300 ft. stand was not excessive.
2 Lower sigma values can be obtained more easily with the higher head, thereby allowing cavitation tests to be conducted conveniently even on Francis runners in the low-specific-speed range.
3 Field conditions of head and sigma can be duplicated for all Kaplan and propeller designs and for many Francis designs, allowing more thorough investigations of actual operating conditions.

The entire wheel case, including wicket gates and operating mechanism, stayring, bottom ring and head cover, is suspended from the dynamometer frame and is entirely independent of the head tank and other components of the pressurised system. This is accomplished by attaching the wheel case to a cylindrical barrel, located in the head tank, but separated from it by means of music-note rubber seals. The advantage of this mounting is that any breathing or other movement of the pressurised tanks will not affect the alignment of the runner and shaft, which is also attached to the dynamometer, and consequently, excessive bearing wear and accompanying extra friction loss and other difficulties are eliminated. To remove the wheelcase, the barrel assembly is removed through the top of the head tank by means of the overhead crane. The wheelcase assembly is then removed and placed on the laboratory floor for convenient disassembly and reassembly. The runner can be detached from the shaft and removed from the stand after lowering the short elbow portion of the draft tube.

In order to determine the value of hydraulic thrust for each individual test point, all rotating parts including turbine runner, shaft and dynamometer rotor are supported by a Kingsbury thrust bearing in the top of the dynamometer stator which in turn is suspended from an Emery load cell by means of a torsion-free rod. The torsion-free rod not only permits convenient determination of hydraulic thrust, but also permits all of the torque developed by the turbine to be transferred to another Emery load cell equipped with an extremely accurate three-range indicator.

After the complete model is assembled in the head tank and the access door is closed and sealed, the entire system is filled with water (which takes about 15 minutes). The pumps are then started and the system is pressurised. All mercury and water manometers are bled and zeroed. Test runs are made at 5-minute intervals, allowing one minute to set the new test conditions, three minutes for the transients to smooth out and one minute for the actual test. These runs can conveniently be made at 3-minute intervals by decreasing the time allowed for the transients to settle, but the 5-minute cycle allows each test point to be calculated and plotted as the test progresses. A complete test on a Francis turbine including power and efficiency, cavitation, and runaway speed versus sigma can be run in four days. Five men are used to conduct a cavitation test. During the design stages, the use of measuring equipment to allow the stand to be operated by one or two men was considered, but it was felt that greater accuracy and more consistent results could be obtained with men taking a number of simultaneous readings on all gauges during a run. Also, direct manometer reading is readily understood and allows cross-checking by the hydraulic laboratory technicians, the company's hydraulic engineers, and visiting customer's engineers during acceptance tests, whereas electronic or other complicated conversion equipment would require the continuous services of instrument technicians. Upon completion of a test, the stand can be shut down, drained, and the runner removed in less than an hour.

Some of the outstanding investigations already carried out with the aid of this circuit are the complete development of the Francis runner, wicket gates and stay vanes for the Brownlee development of the Idaho Power Company and for the modifications to the turbines at the Gorge plant, City of Seattle, to accommodate an increase in head, with corresponding increase in power, from 275 to 325 ft. Extensive model studies are to be conducted for the Ice Harbor Lock and Dam of the U.S. Army Corps of Engineers, the prototype units being 143,000 h.p. Kaplans running at 90 r.p.m. under 89 ft. head. Continuous basic research is being conducted on Kaplan and propeller turbines, with particular emphasis on high-head applications, and considerable research is planned on cavitation in high-head Francis turbines. The S. Morgan Smith Company consider that the results obtained thus far with the new circuit have been most gratifying.

Abstracts from the World Technical Press

Earth and Rockfill Dams

This is an abridged version of a paper included in the course of lectures which was held on the occasion of the Centenary of the Swiss Federal Technical University. It deals exclusively with the usual methods adopted for dumped and rolled earthfills, and rockfill dams. Following a short comparison between fill and concrete dams from the technical and economical point of view, the author deals with material and soil investigations, the various patterns of fill dams, the methods used to ensure imperviousness, fill materials, and foundations. The two final sections are devoted to hydraulic design and stability analysis. (Professor G. Schnitter, Head of the Laboratory for Hydraulic and Earth Structures, Zurich, *Wasser- und Energiewirtschaft*, Vol. 48, No. 2, February 1956, p. 27, 10 pp., 11 ff.)

Lake Hazar Project

Lake Hazar, from which the Tigris takes its rise, lies in a range of the Eastern Taurus about 400 m. above the Uluova plain which the Haringet River, a left-bank tributary of the Murad, bisects from south-west to north-east. Irrigation requirements in the Uluova plain and increasing demands for power in the Elazig-Diarbekr region have combined to prompt the Turkish Ministry of Public Works to develop the power resources of the lake in a two-stage system, the tailwater of which will discharge into the Haringet. This scheme will divert the waters of the lake, supplemented by the headwaters of the Tigris, northwards into the upper Euphrates, about 720 miles north of the confluence of the two rivers near Basra. Lake Hazar will be tapped by a tunnel so as to lower its water level 25 m., thus reducing its area from 82 to 60 sq. km. and its capacity from about 8,000 to 6,100 million cu. m. In accordance with the rate at which power demand increases, it is expected that this block of 1,900 million cu. m. of water will be exhausted within 15 to 20 years by the two power houses which, thereafter, will still have at their disposal an aggregate operating discharge varying between a maximum of 6·815 and 3·752 cu. m. per second. Before generation starts, that is to say, before the lowering of the lake level begins, the diversion of the headwaters of the Tigris into the lake at its south-east tip must be completed, thus reversing the flow in the uppermost stretch of the Tigris and converting its exit from the lake into a supply inlet. This work will involve the erection of three dams which will stop silt from being carried into the lake, and of a pumping plant which will lift the discharge from a catchment of 55 sq. km. on the right bank of the Tigris into the main supply canal of a smaller catchment on the right bank. The intake tunnel 4·5 km. in length and 2·05 m. in diameter, leads through the hill on the north side of the lake to a surge tank, 45·5 m. high and 9·0 m. in diameter, from which a 1,652 m. penstock 1·4/1·1 m. in diameter will feed the upper power plant. The initial operating head of 315 m. will sink in the course of time to 290 m. From the upper plant, an open channel connects, through a small balancing basin, with a 600 m. tunnel which leads to the pressure shaft of the lower plant. This operates under a gross head of about 80 m. The aggregate maximum capacity of this two-plant system at the lowered lake level will be 19,000 kW and its minimum capacity 10,400 kW, corresponding to a yearly production of 166 and 91 million kWh respectively. Once in operation, the Lake Hazar development will greatly relieve the traffic on the single-track Turkish railways of the region, now congested by coal transport. The article contains a detailed hydrological survey of the catchments involved, and deals at the end with the irrigation problem. (H. D. Schmidt, *Die Wasserwirtschaft*, Vol. 46, No. 4, January 1956, 4 pp., 2 ff.)

The Ice Problem in Hydro Plants

A comprehensive survey, in two instalments, is given of ice problems in hydro-electric installations. The formation of ice is first explained: surface ice in lakes, and ground and drift ice in flowing water. The former, except in ice jams, is seldom very troublesome, but ground and drift ice may cause costly stoppages in run-of-river installations. Preventive measures against the formation of such ice are discussed at length. Ice control can be greatly facilitated by the correct canalisation of a river and the selection of favourable sites for weirs. The efficiency of the various patterns of weirs from the aspect of ice control is briefly discussed. In the second part of the article, the various methods of ice prevention are reviewed, and a separate section is devoted to the conditions arising when thawing sets in, and to the best methods of dealing with these conditions. (Dr.-Ing. Karl Theodor Strauch, *Die Wasserwirtschaft*, Vol. 46, No. 4, January 1956, p. 90, 8 pp., 2 ff.; No. 5, February 1956, p. 127, 8 pp., 3 ff.)

The Kreuter Dissipator

The Istrago power station constitutes the third stage of the Meduna Valley development. It operates from a theoretical head of 67·55 m. and produces yearly 42 million kWh by means of two 3,750 kVA sets. The plant incorporates a few particularly interesting features. The surge tank, hydraulically calculated by Professor Evangelisti, of the Bologna Technical University, is designed to divert the discharge (13 cu. m. per sec.) to the tailrace in the event of sudden stoppage of the turbines. To ensure a smooth evacuation of the discharge without oscillations, the overflow shaft of the tank connects with an energy dissipator called after its inventor, Professor W. Kreuter. The cylindrical surge chamber, 55·75 m. in aggregate height, connects with the downstream end of the 2,600 mm. diameter pressure conduit, by means of a branch pipe disposed at an angle of 90°, and encloses a 1,200 mm. diameter bellmouthed central spillway shaft, the top of which is 1·5 m. lower than the top of the tank. The connecting branch pipe emerges in the annular space between the tank and the spillway shaft. This spillway shaft leads to the Kreuter dissipator which comprises a cylindrical stilling tank 10 m. in diameter by 3·8 m. deep, and a central inlet boss of reinforced concrete with bottom admission and radially disposed rectangular outlet nozzles. From the bellmouth to the dissipator nozzles represents a head of

25 m. and at this head the discharge is 13 cu. m. per sec. The energy of the jets escaping from the nozzles is controlled by an appropriate distribution of the water level above and below the middle of the nozzle and is thus dissipated to such an extent as to enable the water to flow over the edge of the stilling tank into the outlet gutter without oscillations. To ensure a smooth flow from the overflow shaft and an equal pressure around the whole of the inlet boss, there are two symmetrically arranged admission pipes. A particular advantage of this dissipator is that the admission boss is designed to act as a shutting and regulating device. Regulation occurs by means of a cylindrical piston which slides up and down from the inner opening of the nozzle crown, thus reducing or increasing the outlet section. (Dipl.-Ing. Tito Ognibeni, Milan, *Die Wasserwirtschaft*, Vol. 46, No. 7, April 1956, p. 174, 4 pp., 5 ff.)

Speeding Up Transmission-Line Construction

A short description is given of two time-saving devices used in the erection of the 123 steel towers which support a 25 mile transmission line of the Pennsylvania Power and Light Company between Martins Creek station and Siegfried substation. The rig used to haul steel to the tower sites is believed to be the only one of its kind. It has a capacity of 7 tons and is equipped with davits in the front and rear of the truck body along the longitudinal centre. The davits operate on either side of the truck body and can be raised or lowered with the load, enabling workmen to pick up the load from the ground and place it on the truck or vice versa. Davits and cables are operated hydraulically from the cab. This piece of equipment contributed to a 41 per cent. saving in the cost of handling and hauling steel on this line, which was recently completed over a terrain that offered far from ideal conditions for excavation. A heavy-duty hole digger was used to excavate for tower foundations. This digger, powered by two 254 cu. in. engines through a torque converter, and coupled through a 3½ in. Kelley bar to augers, bell reamers, or rock core barrels, provided holes 34, 42 and 66 in. in diameter and from 8 to 13 ft. deep. Controls, including stabilising jacks, are operated hydraulically. (R. V. Nuss and J. D. Graver, *Electrical World*, Vol. 145, No. 23, June 4, 1956, p. 41, 2 ff.)

California Water Plan

A water surplus in the north, combined with a water scarcity in the central and southern parts, confronts California with a problem to which nine years of study has been devoted. This article discusses a preliminary report which has been released on this state-wide scheme. In addition to incorporating the existing Central Valley project, the plan will also include the already authorised Feather River project. The plan can be divided into two parts: (1) Features to satisfy local needs (240 reservoirs to store 14 million acre-ft.); (2) inter-basin projects involving transport of water over long distances. This latter part, called the California Aqueduct System, will absorb almost two-thirds of the cost of the whole plan, assessed at $4,000 million, and involve the construction of 33 major reservoirs totalling more than 48 million acre-ft. of capacity, in addition to a complex arrangement of conduits that will carry water from north to south. To mention but a few of these conduits, the Sacramento West Side Canal, a double conduit, will have a length of 167·5 miles; the two conduits which run down the San Joaquin Valley, 235 miles; the two Tehachapi mountain crossings, 127 and 169 miles respectively. Dams include such giant structures as Oroville dam on the Feather River and Beaver dam on the Trinity River, both concrete dams 730 ft. in height, as well as Slate Creek dam on the Klamath River, a 775 ft. high rockfill. Total installed power capacity at the 270 reservoirs is set at 7 million kW with a seasonal production of 31,600 million kWh. But the pumping plants will require 56,000 million kWh a year. It is noted in the report that 22,000 million of this is "needed only for conveyance of water to certain distant desert areas, the development of which cannot be foreseen at the present time." The report urges that the Feather River project be expedited. (*Engineering News-Record*, Vol. 156, No. 20, 17th May 1956, pp. 27/28, 1 map.)

New Niagara Development

Following an historical survey of the evolution of power development on the Niagara River, a description is given of the proposed development plan worked out by Niagara Mohawk Power Corporation, Buffalo, together with four other utilities operating in New York State. This comprehensive plan involves four stages of construction—(1) A 47 ft. diameter concrete-lined tunnel about 5 miles long from the Connors Island intake to the Lewiston power house. This development can utilise about 30,000 cusecs under the full 314 ft. head and will operate in conjunction with the existing Schoellkopf and Adams Stations. The added installed capacity will total about 675,000 kW. (2) A second 47 ft. tunnel adding about 675,000 kW capacity. Schoellkopf station will continue to operate as well as Adams station when water is available within treaty limitations. (3) Pumped-storage development to provide for greater peak-load output at the Lewiston power house, consisting of a single 47 ft. diameter tunnel about a mile long, a pumping-generating station adding 130,000 kW generating capacity and a pump-storage reservoir of about 22,000 acre-ft. (4) Lower river development tunnel about 3 miles long and 42 ft. diameter, to add about 120,000 kW and develop the 94 ft. of head in the lower river between the Schoellkopt station power house and the Lewiston power house. The plan will add approximately 1·6 million kW of installed generating capacity to the existing capacity of the Schoellkopt and Adams stations. The proposed development could be completed in about six years, power from the first step being generated about three years after construction begins. (Harold I. Howell, *General Electric Review*, Vol. 59, No. 3/4, May-July 1956, p. 28, 5 pp., 3 ff.)

Hanabanilla Scheme

This 45,000 kW project, Cuba's first hydro scheme of any magnitude, has many of the elements of a very much larger project, but scaled down and tucked into two narrow valleys of the rugged Trinidad-San Juan Mountains. In other words, a lot of engineering is packed into a fairly small job, entailing as it does an

underground power station 40 × 120 ft. in plan by 75 ft. in height, the diversion of two rivers, two rock- and earthfill dams, Francis turbines operating on a head of 870 ft., and a 4½ mile tailrace tunnel. By damming both the Rio Hanabanilla and Rio Negro, and connecting them by an unlined canal, a 2,500 acre reservoir will be created. The 130 ft. high Jibacoa dam, which will divert the Rio Negro and Rio Guanayara water into the Hanabanilla watershed, will be topped by a small rockfill dam with a rolled earth core that will spread out as an impervious berm on a broad base. All the overflow from the reservoir will spill from its Hanabanilla end. Hanabanilla dam, 154 ft. high from bedrock and 850 ft. long at the crest, will have a rolled impervious core bounded on each side by two rock zones; to its left, a 370 ft. wide saddle-type uncontrolled overflow spillway will be provided by cutting the rock down and inserting a concrete sill. Between the dam and spillway there will be an intake structure leading to a vertical penstock shaft 800 ft. deep and fitted with a steel liner, 8·5 ft. in diameter, backed by concrete. The underground power house, to be ultimately equipped with three 15,000 kW generators, will be reached by an access tunnel about 1,100 ft. in length and 16 ft. in diameter, which will be served by an inclined railway capable of carrying passengers as well as the largest generator part. The free-flow tailrace tunnel is to be a 14 ft. horseshoe section, unlined except where required by poor rock conditions. Average discharge through the turbines will be 165 cusecs initially. Excavation work has now begun and the $300,000 contract for the two generators of the initial installation stage has been awarded to the AEG concern of Germany. (*Engineering News-Record*, Vol. 156, No. 24, June 14, 1956, p. 73, 3 pp., 5 ff.)

Banded Pipes in Penstocks

On the basis of the experience gained in Switzerland (Grande Dixence) and Italy (Santa Massenza, Trento), the advantages of banded pipes in high-pressure penstocks over welded and riveted pipes are reviewed and discussed. It would be interesting to establish a statistical comparison between banded and conventional penstocks as to strength and bursting, but the empirical data gathered so far are too few in number and not sufficiently systematic for the criterion of statistical frequency to prevail over the criterion of probability. (Dr. Ing. Antonio D. Bruzzone, General Manager of Acciaieria Tubificio di Brescia, *Indian Journal of Power and River Valley Development*, Vol. VI, No. 4, April 1956, pp. 3 to 5, 3 ff.)

World's First Tidal Power Plant

The possibilities are discussed of the EDF tidal scheme on the Rance estuary which is scheduled for completion in 1963 and will add 800 million kWh yearly to the French power supply from its 342,000 kW of generating capacity. To the advantage of one of the best sites for a tidal project anywhere in the world, EDF has added the "monobloc" generating unit, also called "bulb unit," in which turbine and generator are mounted in the same housing (WATER POWER, October 1954, p. 403, January 1956, p. 40, June 1956, p. 221, and July 1956, p. 259). The Rance tidal power plant, sited upstream of St. Malo and the adjacent towns of St. Servan and Dinard, will be in the form of a hollow dam containing 38 power units and flanked on either bank by 10 gates to aid in filling and emptying the reservoir. The whole structure, which will carry a roadway across its top, will be about 2,300 ft. in length and rise about 85 ft. above the bottom of the estuary. Navigation will be ensured by a lock built on the left bank. The volume of concrete required for the entire installation is estimated at 615,000 cu. yards. Construction will involve the setting up of an enormous cofferdam, since equal protection must be provided both on the sea and reservoir sides. Also provision must be made to pass the entire tidal flow four times each day and in such a way as to minimise the effects on tide levels both up and downstream. EDF are fully confident that this gigantic venture will prove a success. (Waldo G. Bowman, Editor, *Engineering News-Record*, Vol. 156, No. 24, June 14, 1956, p. 37, 6 pp., 8 ff.)

Line Stringing by Helicopter

Combination of a helicopter and a tension wire stringer solved the stringing of 203-MCM ACSR conductors across two wide stretches of water for Puget Sound Power & Light Company. The helicopter pulled in a lead line over Deception Pass, a 2,000 ft. channel of extremely fast tidal currents and short ebb tide, and for a 2,250 ft. crossing above Cornet Bay, both on Puget Sound. Tension stringing held necessary right-of-way clearing to a minimum on the heavily timbered slopes of Goose Rock State Park and obviated the need for a boat during the stringing operations. A ½ in. manila rope was carried by the helicopter from north to south across Deception Pass and over the trees. Then a $\frac{7}{16}$ in. wire running line was pulled in to string the conductors. Stringing tensions of 5 to 6,000 lb. were maintained with the tension stringer and the conductors were sagged to an initial tension of 6,738 at 60° F. Cornet Bay was strung in a similar manner, except that the helicopter carried a ¼ in. line. This span also was sagged to a somewhat lower tension, as the tree clearance problem was not present. (Malcolm Cropley and Leland Petitjean, *Electrical World*, Vol. 145, No. 23, June 4, 1956, p. 43, 3 ff.)

Utilisation of Power Resources in U.S.S.R.

This report on the planned integrated utilisation of power resources in U.S.S.R. contains interesting data on hydro-electric developments now under construction. The two Volga giants at Kuybyshev (2·1 million kW) and Stalingrad (1·7 million kW), together with the Dahovka plant, will upon completion add another 4 million kW of installed capacity to the generating equipment of the country, corresponding to a yearly production of 21,000 million kWh, not to mention navigation facilities, water supply and irrigation. It is estimated that these three plants alone will bring about an economy of 11 million tons of coal a year, and halve the cost of power in the Central and Volga power systems. The general development of power resources and the co-ordination of thermal and hydro-plants are reviewed. There are now 50 co-ordinated power systems within the Soviet Union. (The U.S.S.R. Delegation to ESCAFE Conference on Electric Power, *Indian Journal of Power and River Valley Development*, Vol. VI, No. 4, April 1956, p. 13, 6 pp.)

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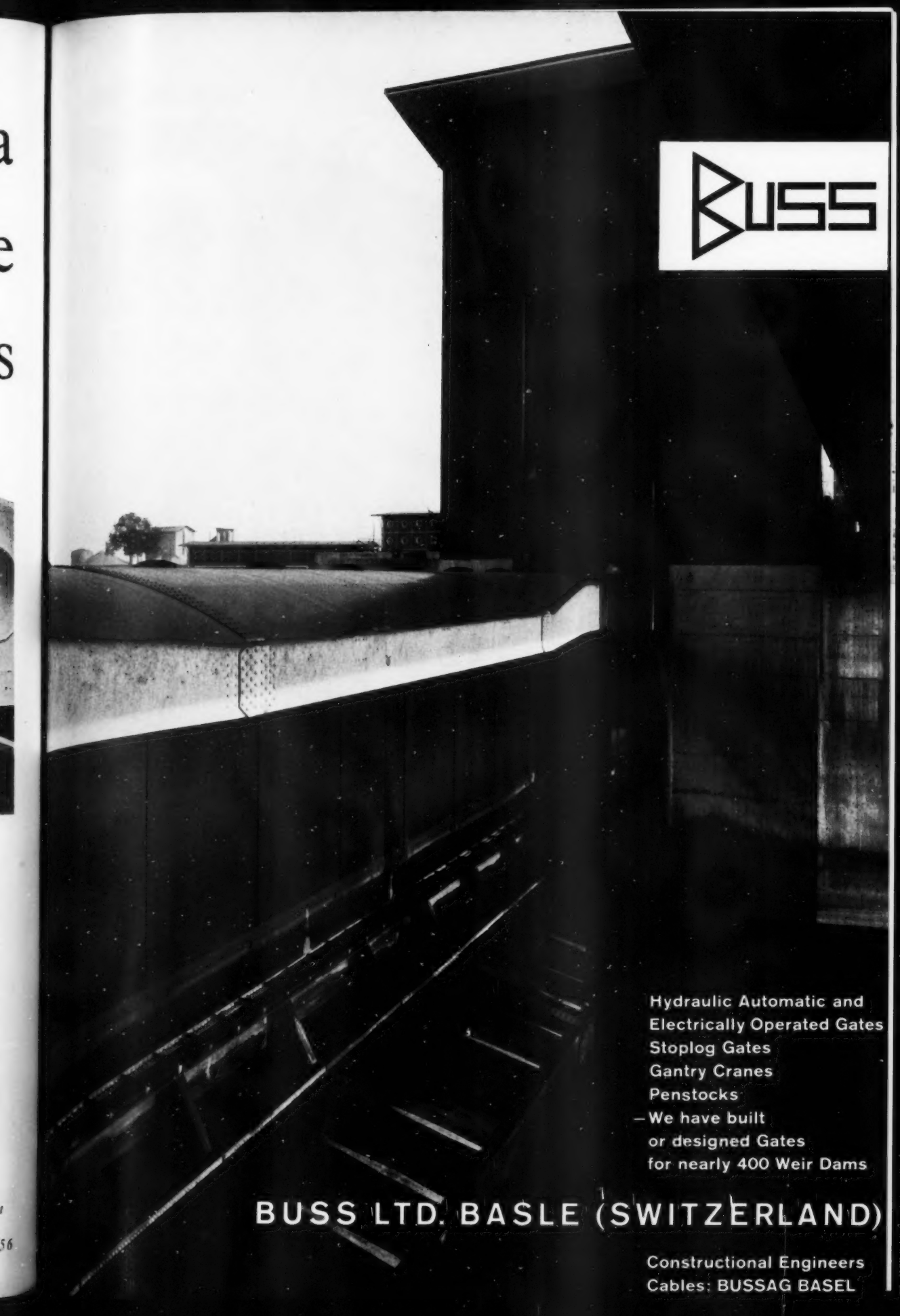

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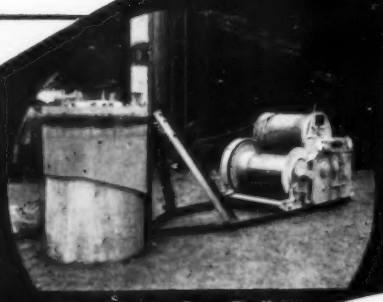
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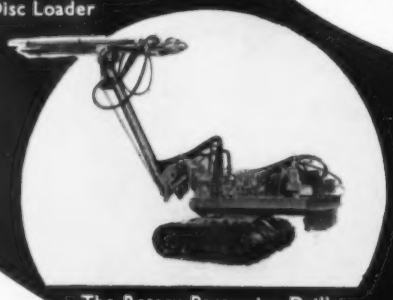
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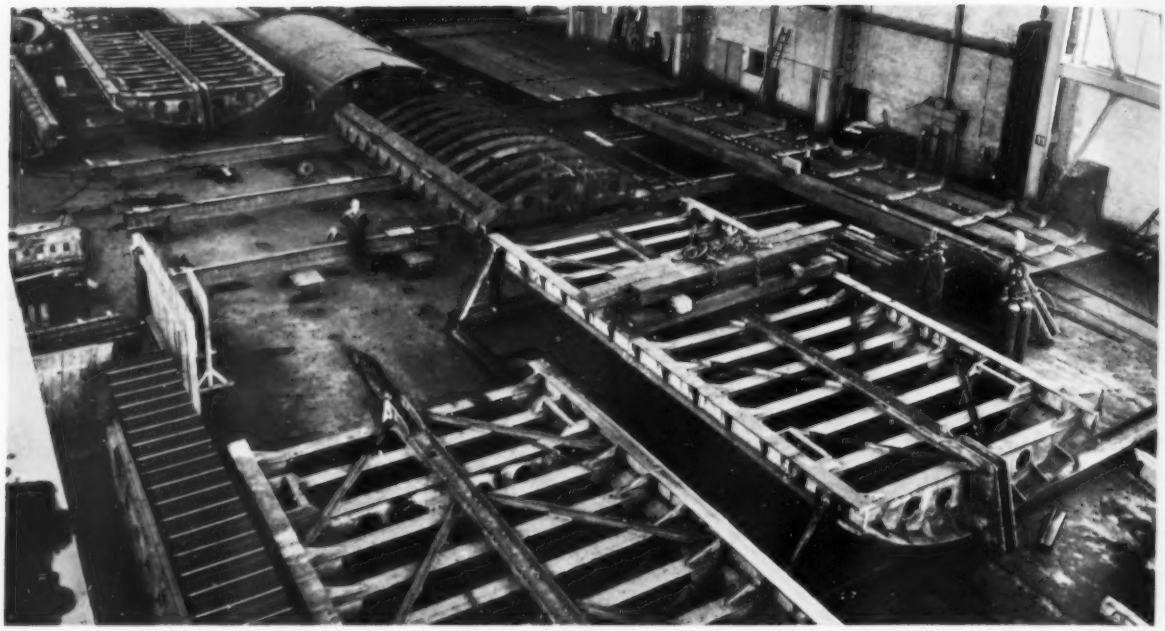

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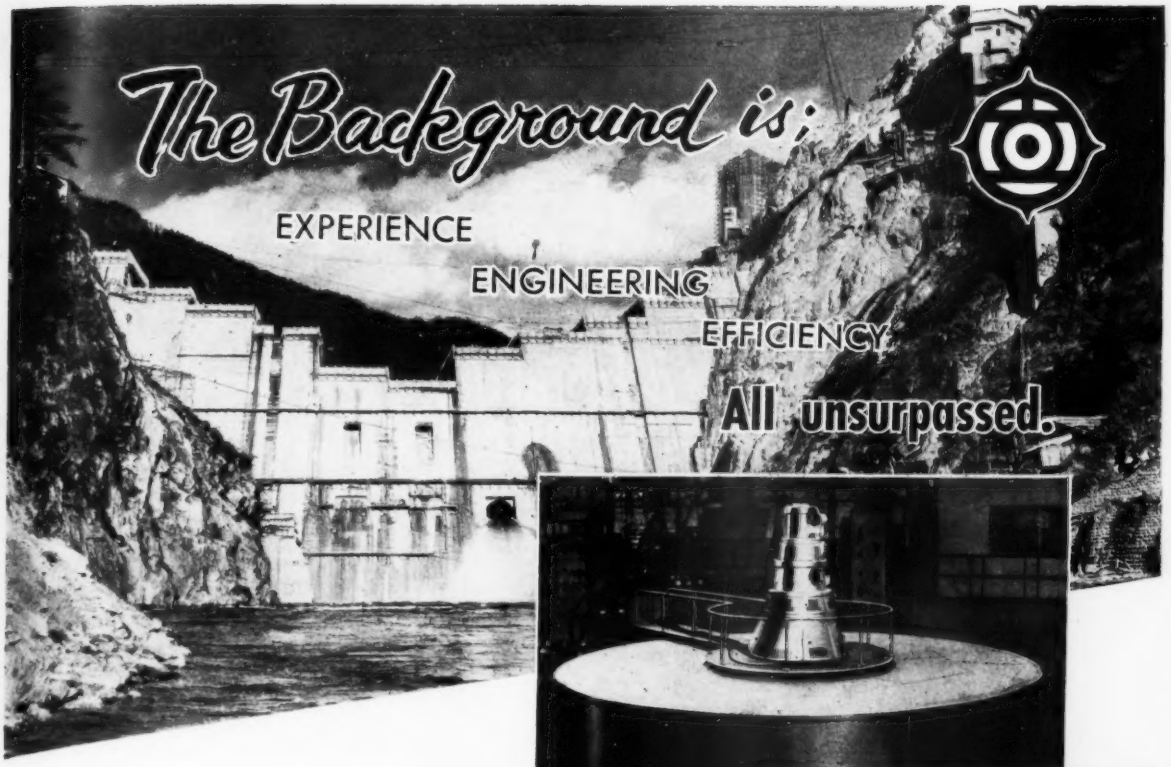

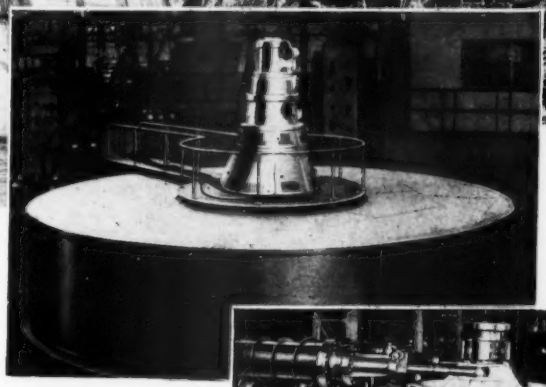

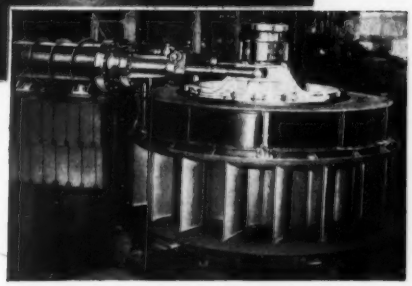

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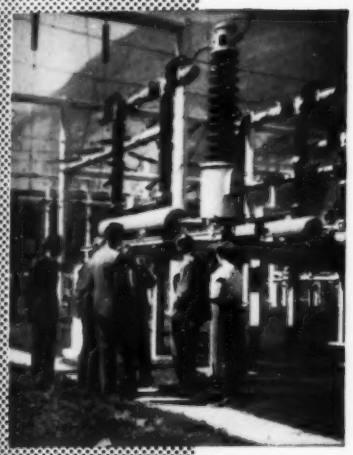

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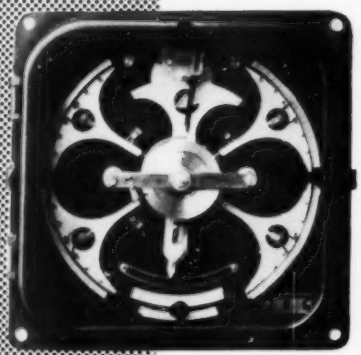

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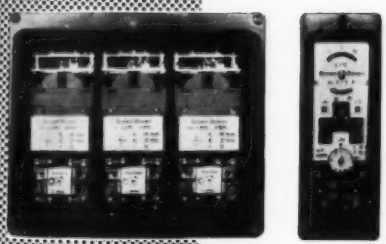

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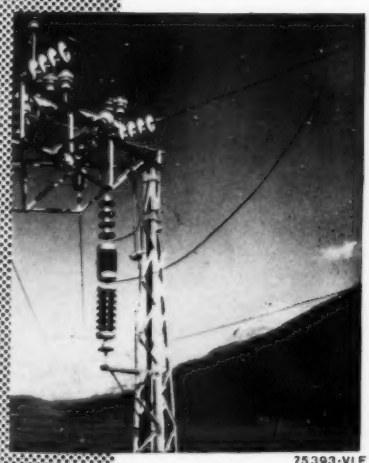

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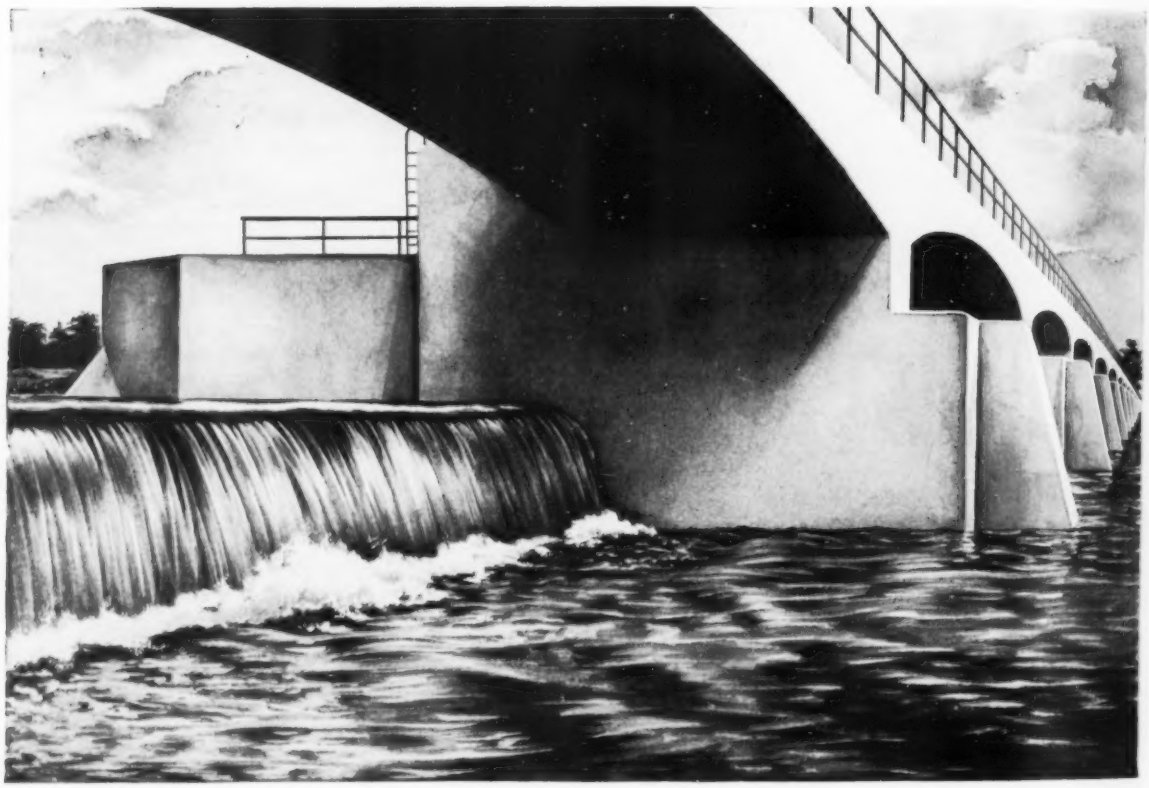

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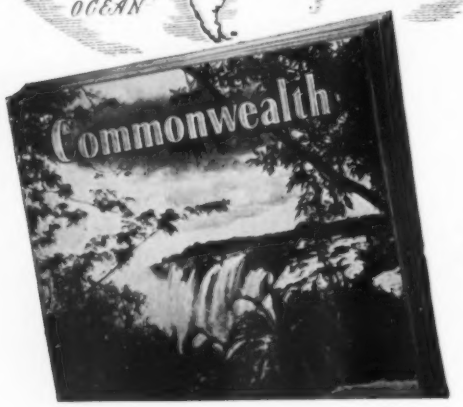

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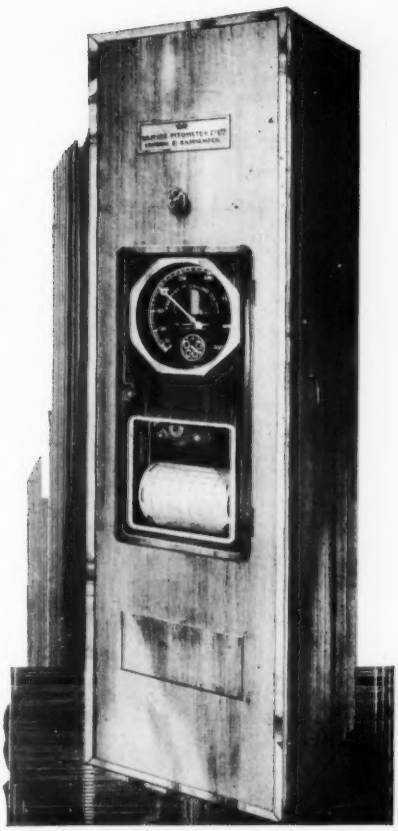

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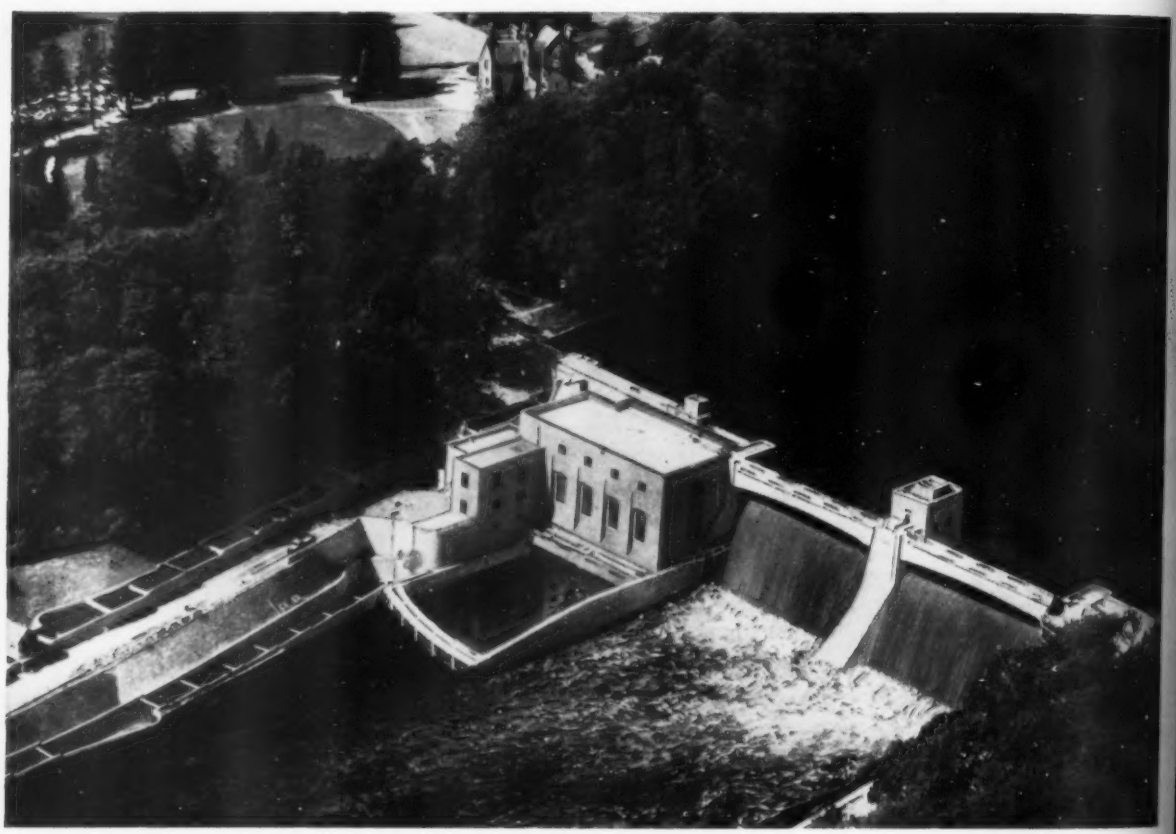

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